MAPPING ACUPUNCTURE POINTS USING MULTI CHANNEL DEVICE

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Introduction

Acupuncture has been used as a therapeutic modality since the beginning of recorded history and is currently utilized by over one quarter of the world's population. In clinical practice acupuncture has proven to be a relatively safe and effective therapy, the main use of which is in the treatment of pain and addiction. The current integration of acupuncture into Western medicine however, is based on clinical rather than scientific grounds for as yet there is little understanding of how acupuncture achieves these results.

The practice of acupuncture involves the stimulation of specific points on the skin called 'acupuncture points' which are small regions of local or referred pain that are more sensitive than surrounding tissue. Drawings and figurines describing acupuncture points and meridians, which are lines linking these points into functional groups, have been used by traditional Chinese physicians for centuries and are still used by modern acupuncturists as a guide to therapy. The reality of acupuncture [1]points however, is often questioned for no consistent structural correlates for them have been identified. While acupuncture points are not associated with any unique anatomical structures, they can be objectively identified using electrical parameters. In

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particular, acupuncture points have been found to be points of low electrical resistance compared to surrounding tissue [1,2,3].

The significance of the unique electrical properties of acupuncture points is uncertain at present. The physiological basis for these altered electrical properties has been attributed to regional hyperactivity of the sympathetic nervous system, which may affect both sweat gland activity and blood flow regulation. Alterations in skin resistance have also been shown to relate to temperature, the thickness of the stratum corneum, the amplitude and frequency of stimulation and the pressure on the recording electrode [4]. As well as varying with objective parameters, skin conductivity has also been shown to vary with subjective sensations of pain, with painful areas demonstrating a reduced skin resistance. A close correlation has also been shown to exist between acupuncture points and musculoskeletal 'trigger points' which are points of localised tenderness [5].

The fact that acupuncture points can be identified subjectively as tender points and are found to have characteristic electrical properties suggest that they are functional entities rather than structural ones. These functional properties may be used diagnostically in a clinical setting as pathology in a particular body location has been shown to correlate with increased tenderness and electrical conductivity of the 'corresponding' acupuncture point. The clinical assessment of acupuncture points is generally accomplished using palpation or via an electronic 'point locator', which measure the DC resistance of points compared to surrounding skin [6].

Commercially available point locators utilise a metal locator probe and an indifferent electrode and produce an auditory output (usually a high pitched tone) when a point is located. These devices however, are open to criticism. They are unable to control for local variations in skin thickness, surface secretions, or pressure placed on the electrode [2], and are only able to measure a single point at a time. These make them time consuming to use and subjective to user bias in point selection. Furthermore these devices do not store data and are therefore unsuitable for producing a map of skin resistance, which can be accessed over time. To overcome some of the limitations of currently available single probe devices, we have designed a multi-channel probe capable of measuring and then mapping the skin resistance of multiple points.

Method

We have designed a probe that consists of 256 pins in a precise 16 x 16 square grid pattern. The probe is placed on the skin so that the pins slide freely allowing the weight of each pin to apply a constant pressure at each contact point. The probe is then connected to a 16 x 16 multiplexer configuration. The output of the multiplexer goes to a Wheatstone bridge. A regulated 5 volts DC is applied between the top and bottom of the Wheatstone bridge to power the 2 branches. The voltage different taken from the mid point of the 2 branches result in a ratio between the reference resistance and the skin resistance measured by the probe, and this voltage is then passed to an analog to digital converter (ADC). The digital signal is then sent to the parallel port of a PC. The measurement cycle for all 256 pins is 120 seconds, short enough to prevent polarisation effects during measurement [3].

The whole process is controlled by dedicated software designed for the purpose. The software controls the initialization of the probe, the pin selection sequence, data logging, filtering and compensation of the acquired data, as well as the plotting of the skin resistance map. Selection of the grid size is also done via the software by setting the number of columns to read from the probe. The resulting output is a shaded contour plot with darker shade showing points of low electrical resistance on the skin, which may correspond to classical acupuncture points.

Hardware Design

The multi-channel probe has been designed with up to 256 channels, with each channel having a stainless steel flat-ended pin acting as an electrode. Each pin is 1mm in diameter. The electrode array used has 256 points spaced 5mm apart which cover an area of the skin measuring 8 cm by 8 cm. Each pin is allowed to slide freely along its length so that the weight of the pins applies constant pressure at each contact point. The pins are connected to 16 multiplexers. These are the MPC506A, which are single-ended 16-to-1 channel CMOS analog multiplexers (Figure 1). This 16 x 16 pins grid configuration connected to the 16 x 16 two-tiered multiplexer expansion, which enables the 256 pins to be selected sequentially during measurement. The channel selection is achieved via a high-performance, CMOS silicon-gate, dual 4-stage binary ripple counter, the 74HC393. The two 4-bit counters are cascaded together to provide an 8-bit counter, thus giving 256 possible selections. The 4 least significant bits of the counter are connected to the 16 first stage multiplexers, while the 4 most significant bits are connected to the stage two multiplexer. The output of the stage two multiplexer then goes to a Wheatstone bridge, which uses two 1 megaOhm (1MΩ) resistors on one of its branches. The other branch is made up of the skin resistance between the palm and the back of the hand as reference resistance (Rf), and the resistance between any single pin electrode on the probe and a point on the skin near the area to be measured. Depending on the area to be measured, the resultant measurement could either be transversal or longitudinal. The voltage resulting from the imbalance of resistance between the 2 branches of the Wheatstone bridge provides the ratio between the reference resistance, which is constant, and the resistance being measured. The signal is then fed through a pocket sampler [8], which act as a data logger.

The functionality of the pocket sampler had been extended through the modification of the control software to provide a RESET signal from pin 17 of the SK2 DB25 socket incorporated in the design of the sampler. A CLOCK signal is also extracted from the sample to provide synchronisation of the channels selection and data logging. The digital output from the pocket sampler is then sent to the PC through the parallel port. (Figure 1)

Software Design

During measurement, the pins are placed on a skin area and the whole process of the measurement and the data logging sequence is controlled via the computer software developed for the probe. This software is written in C++ using the object-oriented programming method and controls the initialization of the probe unit and the data logging unit, the pin selection sequence, data logging, etc. Figure 2 shows a flow chart for the software. The software will first check for the existence of the system and then initialize the multiplexer unit and the analog to digital converter unit. When the data logging starts, it controls the selection of the channels, and samples and holds the data in the analog to digital converter, which converts the analog voltage to an 8-bit digital data. The software then selects the higher nibble, which is the 4 most significant bits of the 8-bit digital data, and reads it via the status register of the parallel port on the PC, followed by selecting the lower nibbles and reads it. Consequently, it combines both high and low nibble together to get back the original 8-bit data. The software saves the data in the memory and plots a graph of the data versus time as it comes into the stream. The data, once collected, can be saved to a file. The measurement cycle for all 256 pins is about 120 seconds so that each point has a voltage applied for less that 0.5 seconds which should be short enough to avoid polarisation of cells [7].

In order to produce the final resistance map, points were plotted every 1 mm using an interpolation method similar to a spline function [9]. This function was used to interpolate the voltage distribution between the four normalized values which were measured from the electrode array which had electrodes spaced 5mm apart. After calculating the normalized value for every millimeter, points were assigned a colour according to their value, with the colour changing in increments of 0.022 normalized units. The resulting map was plotted using the Microsoft Excel standard graph function.

Results

Figure 3 shows an example of a skin resistance map produced by the multi-channel skin resistance mapping probe. To produce this map, a 16 x 8 array was selected via the software, which produced a grid of 128 points over an area of 8 x 4 cm. This array was applied to the anterior surface of the lower arm and the back of the lower arm directly under the area was used as the second point, as shown in figure 4. Measurements were done sequentially from pin 1 to pin 128 as indicated by the numbers in figure 3 and 4. 5 subjects were measured in the experiment. The example in figure 3 is the resulting map for one subject for which 3 repeats were done. It represents a shaded plot with light areas representing higher resistance and dark areas representing lower resistance. The map produced shows that areas of particularly low resistance can be identified. These points are proposed to correspond to acupuncture points. Furthermore the map showed that these points are distributed longitudinally along the forearm which is consistent with the Chinese theory that points are connected along a low resistance pathway or 'meridian'.

Discussion

The probe described in this paper has many advantages over conventional acupuncture point locators. The ability to measure the resistance of multiple points with a single application of the electrode overcomes the user bias in point selection that may occur with single point electrodes. Using a PC to log the data also ensures that the same time is spent measuring each point and that the total exposure time of the skin to electrical stimulation is short enough to prevent polarisation of the cells. The use of the weight of each pin to provide consistent pressure to each point also helps to remove potential user bias that may occur with existing devices, which depend on the user to apply pressure on a single handheld electrode.

The most useful features of the device is the fact that it produces a skin resistance map produced by simultaneous measurement of the whole area and thus objective determination of acupuncture points with respect to surrounding tissue. This has many advantages over the auditory output produced from single point devices. The map produced by this device may be printed out and retained for future reference thus enabling comparisons to be made between different subjects or for the same subject at different times. This device therefore allows resistance maps to be followed over the course of an illness, as well as allowing resistance maps with similar conditions to be compared thus enhancing the study of the relationship between illness and the electrical properties of acupuncture points.

In order to correlate the resistance map with the location of traditional acupuncture points, it is necessary to accurately define the outline of the electrode grid on the body surface so that the location of anatomical landmarks used to locate acupuncture points can be accurately determined. One limitation of the current device is that the electrode array only covers an area of 8 cm^2. However, multiple readings can be taken from the same patient over different 8cm^2 blocks, thus building up a picture of skin resistance over a large area. Furthermore, provisions have been made in the software to vary the number of electrode pins thus allowing the measurement of either a larger total area or the same area with a reduced spacing between the pins so as to produce a map with a finer resolution.

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Figure Legends

Figure 1

Design Schematic – Multi-Channel Resistance Probe

Figure 2

Flow Chart for Sampler's Software

Figure 3

A Shaded Plot of a Skin Resistance Map of the Anterior Surface of the Lower Arm.

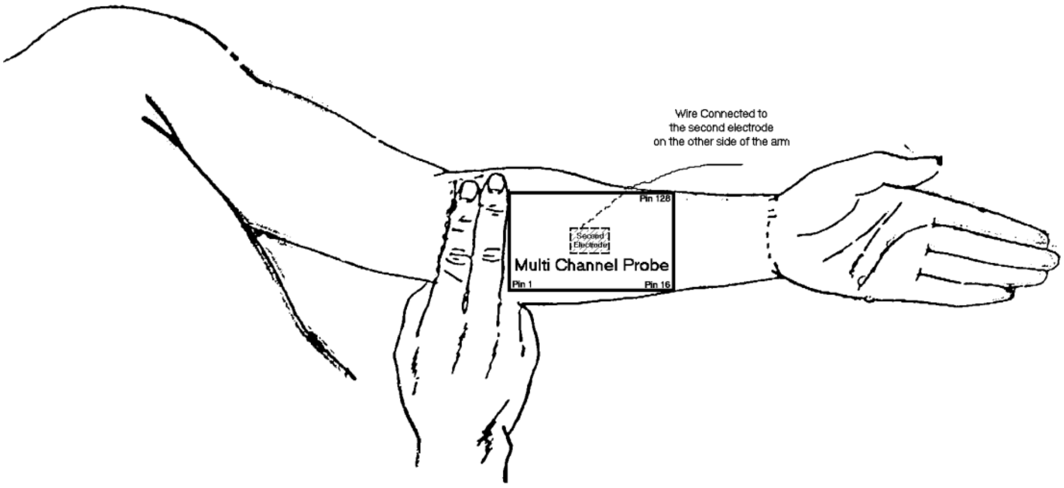
The light areas represent higher resistance and dark areas represent lower resistance.

Figure 4

Position of the multi-channel probe on the Anterior Surface of the lower arm.

Measurement is done longitudinally as indicated by the position of the pin numbers.

The second electrode is presented in hidden view, as it is on the back of the arm.


Wire Connected to
the second electrode
on the other side of the arm
Pin 128
Second
Electrode
Multi Channel Probe
Pin 1
Pin 16