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A Bioelectric Model of Meridian Channels in Pain Control and Wound Healing with Noninvasive Rectangular Pulse Electric Current Stimulation (RPECS)

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Abstract

Questions:

What are the meridian channels? Where do they locate if they exist? Â How do they function to control pain or cure diseases? The answers are not fully clear or confirmed today to our best knowledge.

On the other hand, it is well known that noninvasive rectangular pulse electric current stimulation (RPECS) has been applied in pain control and wound healing clinically. However,Â what rolesÂ the meridianÂ channels play inÂ RPECS applications is unknown either.

Methods and Results:

In this study, referringÂ to published preclinical experimental resultsÂ and applying scientific theories or models,Â we propose a bioelectric model of meridian channels in pain control and wound healing with noninvasive RPECS. We alsoÂ discuss a clinical case report (study) to support our model.

Conclusion:

Our current and previous experimental results support our models of meridian channels. Â Meridian channels not only provide transportation canals for matters, energies and information, but also provide electric circuits for RPECS. Meridian channels play important roles in both the pain control and wound healing. Wound healing plays a major to eliminate the pain. RPECS mostly and directly inhibits or controls the pain when it is in using rather than eliminates or removes the pain after using it. However, RPECS could enhance wound healing; therefore it indirectly eliminates the pain.

1 Introduction

Theories regarding meridian channels (Jing Luo in mandarin Chinese) have been documented in the traditional health and medicinal book entitled HuangDiâ€™s Internal Classic (also known as Inner Canon of the Yellow EmperorÂ and HuangDi NeiJing in mandarin Chinese),Â written in China between 221 BC and 475 BC [1]. The book goes into detail regarding theories of meridian channels in the human body and acupuncture analgesia. According to the theories, if acupuncture is performed at, or around, acupoints along the meridians various diseases, particularly those pain-related, can be cured or controlled (managed) [2, 3].

However, what are theÂ meridian channels? Where do they locate, if they exist at all? Â How do they function to control pain or cure diseases? The answers are not fully clear or confirmed today, to our best knowledge.

To define the meridian channels in modern western medical science, in our previous studies [3 - 6], based on medical data, physical chemistry, anatomy and histology, we modeled the meridian as a physiological network system. We think, the meridian channel system is mostly constructed with interstices in or between systems of the cardiovascular, lymphatic, integumentary, nervous, muscular, skeletal, endocrine, respiratory, digestive, urinary and reproductive as well as between the systems and fatty tissues. The meridian channel system would not have its own envelope; it just uses other envelopes of the physiological systems as its envelope. The meridian channels would also use sweat (including mammary) and sebaceous glands as its ports to exchange information, energy and matters between our bodies and environments.Â We believe that major components in the meridian channels are loose connective tissues that consist of electrolytes, cells and proteins; the electrolytes provide rich fluids and ions for processing, propagation or transportation of information, matter and energy. Similar to systems of the cardiovascular, lymphatic, endocrine, nervous, respiratory, digestive and urinary, the meridian channel system should be unblocked according to the theory of Chinese medicine. If the systems are blocked, diseases could occur.

To manage pain, more than 25 years ago, we discussed [7] and proposed a protocol [8] of pain control with the noninvasive RPECS on acupoints in the meridian channels.

In one of the above of our previous studies [3], we proposed information models of (electric) acupuncture analgesia and meridian channels

We also proposed methods and discussed a clinical case report of preventions and treatments for gout or gouty (acute) arthritis and managements for the related pain, with massages and warm running water through the meridian channels [5].

We believe that the fluids inside of the blood vessels can diffuse into the meridian channels much more around the joints than the others or can be easily pumped out into the meridian channels by the joint movements [5 - 6].

We think the water enters and cleans the meridian channels by sweat glands and with negative (subatmospheric) pressure [5 - 6].

Today, it is well known that RPECS can be applied in clinical pain control and wound healing clinically; the benefits to RPECS were discussed in our previous studies [7]. Â However, we have not found any bioelectric model of meridian channels in pain control and wound healing with RPECS in a perspective view of biotechnology insights.

In this study, we propose a bioelectric model of meridian channels in pain control and wound healing with noninvasive RPECS and discuss a clinical case report (study) to support our model.

2 Materials and Methods

2.1 Materials

In the clinical case study, a female patient of 60 years old, complained pain and slow wound healing from her ankle trauma withÂ cellulitis,Â agreed and participated.

A RPECS stimulator TESS™Â 7000, noninvasive conducting carbon conforming electrodes (7.6 cm x 7.6 cm), cotton gauze, medical/physiological saline, medical sticky tapes were used for pain control and wound healing.

Â

2.2 Methods

We refer to preclinical experimental data [7] and apply scientific theories or models [3-7] in the bioelectric modeling study.

In the clinical case study, we used noninvasive RPECS with128 Hz frequency, 120 us pulse width, averaged electric current densities: about 4 mA/cm^2, to stimulate the cellulitis wound on the participantâ€™s ankles, to control the pain and to enhance the healing,Â 30 minutes daily in the experimental investigation. Longitudinal comparisons of pain control and wound healing were performed on the participant. The pain feeling was quantified to 11 levels, level 10 denotes the most painful and level 0 means no pain. The patient felt a mild or pleasant pain (level 1) with our treatment of the electric current density.

The wound healing was somatosensorily assessed according to pain levels as well as visually evaluated based on trauma size.

3 Modeling Developments

3.1 Functions of Meridian Channels in Skin Animal Model with RPECS

Because pig skin is more similar to human skin, and more economic and suitable than other animal skins, domestic pig skin have been often applied as skin animal models in cutaneous studies [7].

In this study, referring to experimental results of preclinical trials, in vitro pig skin conductivities at a tissue level [7, 9] and in vivo electrical potentials (voltages) in pig skin at an animal levelÂ with noninvasive RPECS [7, 10] as well asÂ applying scientific theories or models, we buildup our bioelectric model of meridian channels in pain control and wound healing with noninvasive RPECS.

3.1.1 In Vitro Preclinical Experiments at a Tissue Level

Figure 1 shows a device to measure in vitro electric (tangential) conductivities between two points in a freshly excised pig skin (derma and epidermis, see Figure 2) with a 4 electrode system at a tissue level [7]. Figure 3 is an oscilloscope image that presents a typical waveform of a potential difference [7]. The waveform demonstrates the conductivities can be approximately considered as a resistance. The result in the perpendicular direction is similar to that in Figure 3.

3.1.2 In Vivo Preclinical Experiments at an Animal Level

Noninvasive conforming electrodes and RPECS were applied in our previous in vivoÂ experiments [7]. A conforming electrode is defined as an electrode made of flexible material that will â€œconformâ€• to the curvature of the body surface upon an even and tight contact with the skin. The conforming electrode is composed of carbon rubber sheet and hydrogel Vigilon dressing or sterile saline, gazes as a dispersive agent (conducting median), see Figure 4.

Figure 4 shows a picture to measure in vivo potential differences (voltages) between two points in pig wounded skin with a 4 electrode system at an animal level, where noninvasive conforming electrodes were applied and the negative electrode is the reference [7].

Figure 5 is an oscilloscope image of the measurements, the figure demonstrates three typical waveforms, the highest level represents a voltage between the two noninvasive electrodes, the middle denotes that between a point on the skin and the negative, and the lowest shows that between a resistor and the negative. The lowest can be used to calculate the instantaneous electric current. The results also show the conductivities can be approximately considered as resistances [7].

We measured electric fields under and between the electrodes with RPECS, and we found the fields (intensities) are approximately and respectively uniform under and perpendicular to the electrodes; they are stronger under than between the electrodes [7, 10].

For the normal skins without any wound, both conducting and displacement currents are involved between the electrodes and skins. Therefore, the electric potential waveforms will show saturations [7].

3.2 Bioelectric Model of Meridian Channels with RPECS

Based on the above experimental results, we believe that: with RPECS, the electromagnetic characteristics of meridian channels are mostly like electric resistors; we can ignore the capacitance and inductance in most cases; and roughly consider the channels are filled with electrolytes, the main components of the electrolytes are HO-, H3O+, Cl-, Na+ [3 - 6], the electrolytes have high conductivities; we can use simple Ohmâ€™s law to roughly describe the relationship of the current, voltage and resistance, the distributed form of the law is: J = c E; where J is an electric current density, E is electric field intensity and c is an averaged electric conductivity of the channel electrolytes [7, 9].

Figure 6 shows our model of meridian channel in vivo skin under a noninvasive conforming electrode, the meridian channels are mostly consist of sweat and sebaceous glands or wounds.

Our previous modeling calculations indicate that the sensory fibers would receive the strongest stimulation (about 100 times stronger) compared to other cells in skin because the fibersâ€™ lengths are generally much larger than the other cellsâ€™ sizes [7].

The sensitivity of the nerve fibers to the stimulation could protect normal skin cells from harmful electroporation as well as make pain feeling. Considering the sensory information of both excitation threshold and electroporation, we proposed a theoretical range of the pulse current density for safe application with RPECS. Our modeling calculations and experiments show we just feel mild or pleasant pain when applying safe threshold excitations for pain control [3] or wound healing [7] with RPECS.

Figure 7 demonstrates our bioelectric model of meridian channels with noninvasive RPECS in vivo tissues; the channels not only provide transportation canals for matters, energies and information, but also provide electric circuits for RPECS.

4 Discussion

4.1 A Clinical Case Study

Here, we discuss a clinical case study to support our models in this article.

AÂ female adult of 60 years old traveled to Chengdu, China and accidently had an ankle trauma. TheÂ trauma was diagnosed (day 0) asÂ cellulitisÂ at the ER (emergency room) of a local hospital in Chengdu and treated with 2 IV antibiotics Â (Intravenous) in the hospital for 7 days.Â On day 3, an ER doctor cut the patient's blister to clean the pus with drainage.

The cut wound was not healed in Chengdu China, the cellulitis infection was also not controlled completely. After the 7 days of treatment, the patient was transported back to USA by 2 days of flight tour

Figure 8 shows the wound and drainage on day 10 (a ruler was not shown). We measured the cut wound that was 3 mm x 10 mm in size and 15 mm in depth.

After arriving in the USA, the patient took 2 other prescribed stronger antibiotics by oral medication for total 20 days. On day 31, the cellulitis infection was controlled. However, the cut wound was only about 60% healed by eye observation, see Figure 9. The patient also complained of pain at level 8 or 9 with the wound and felt the wound healed too slowly and worried that the acute could develop the chronicÂ andÂ could getÂ infection again.

Therefore, we applied noninvasive RPECS to control pain and enhance wound healing from day 31 post diagnosis, because electrical current stimulation has been frequently used in both preclinical and clinical investigations of pain management andÂ cutaneousÂ regeneration without infectionÂ [7].

Figure 10 shows our treatments of the pain control and wound healing with noninvasive RPECS. An Ampere meter (not shown) was used to measure the time averaged electric currents. Figure 11 illustrate the wound healing result after 1 day treatment of RPECS on day 32, and the cut wound was more than 80% healed by eye observation.

The patient was feeling her pain was reduced to a level 1 or 2 while the wound was being treated with RPECS and was about at a level 6 or 7 after the wound was treated with RPECS; and the more the wound healed the less the pain was felt.

We observedÂ the wound healed faster after using our noninvasive RPECS treatments than before, by longitudinal comparing pain feeling levels between before and after RPECS treatments, though it was difficult to quantitatively evaluate the wound healing by observation in this clinical case study. Figure 12 shows the wound healing result on day 11 after RPECS treatments, i.e., day 42 post diagnosis, the cut wound was obviously almost 100% healed. However, the patient still felt a level 5 of pain when no RPECS treatment. Â

Figure 13 shows the completely healed wound with a ruler and forceps 6 months post diagnosis. The patient felt a level 1 of pain.

The results indicate thatÂ the wound healing had eliminatedÂ the pain; RPECS itself did not eliminate pain, ratherÂ it controlledÂ the pain. Therefore, RPECS enhanced wound healing [7], and could indirectly remove the pain feeling. The anesthesia effects of RPECS are consistent with that of our previous theoretic modeling study [3].

4.2 General Discussion

We consider and believe that Meridian channels provide electric circuits for RPECS in skin and tissues under or between the electrodes as well as canals to transport or input and output matters, energy and information. Although we used RPECS in our studies, we think the principles of the functions of meridian channels are also applicable to other wave forms of electric stimulation.

We believe there are virtually no side effects for pain control and or wound healing when using mild or pleasant pain levelsÂ of electric intensity with our noninvasive RPECS.

The electric stimulation is very convenient and an economic solution for pain control and wound healing for daily life, especially for travels, such as travelling in flights, trains, buses or cruises.

5 Conclusion

Our current and previous [7] experimental results support our models [3 - 6] of meridian channels.Â Meridian channels not only provide transportation canals for matters, energies and information, but also provide electric circuits for RPECS. Meridian channels play important roles in both the pain control and wound healing. Wound healing plays a major to eliminate the pain. RPECS mostly and directly inhibits or controls the pain when it is in using rather than eliminates or removes the pain after using it; its effects are similar to that of using anesthesia drugs. However, RPECS could enhance wound healing; therefore it indirectly eliminates the pain.

Illustrations

Illustration 1

Figure 1. A device to measure in vitro electric (tangential) conductivities between two points in a freshly excised pig skin with a 4 electrode system at a tissue level.

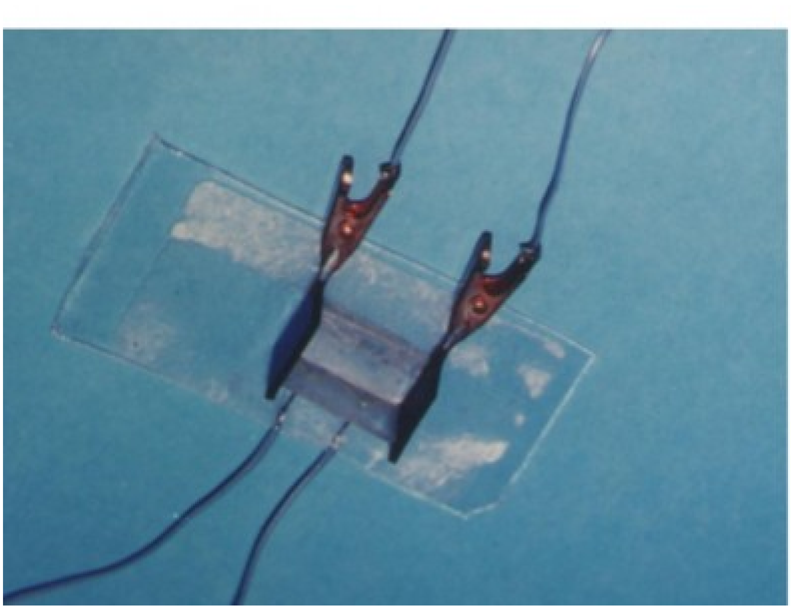

Illustration 2

Figure 2. A freshly excised pig skin (derma and epidermis).

Illustration 3

Figure 3. An oscilloscope image that presents a voltage between two points in a freshly excised pig skin (Figure 2) with a 4 electrode system (Figure 1) at a tissue level.

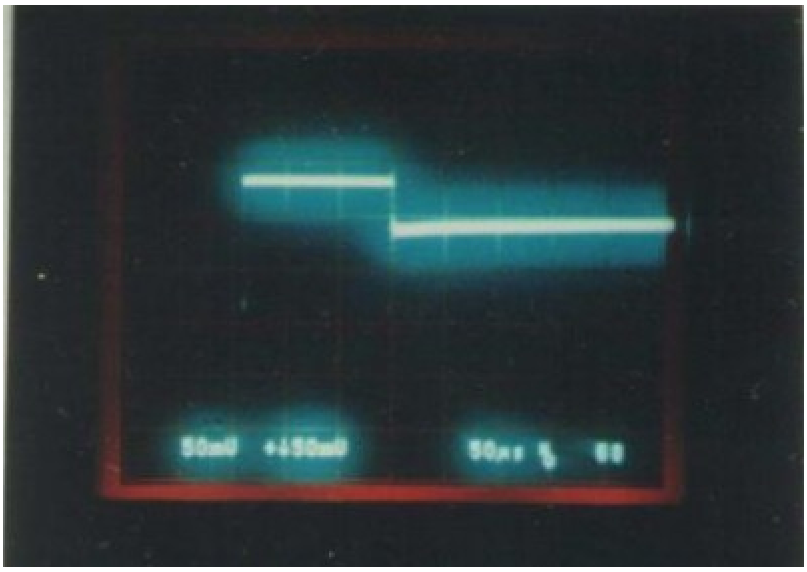

Illustration 4

Figure 4. A picture to measure in vivo potential differences (voltages) between two points in pig wounded skin with a 4 electrode system at an animal level. Noninvasive conforming electrodes (black square sheets) and RPECS were applied, see the text.

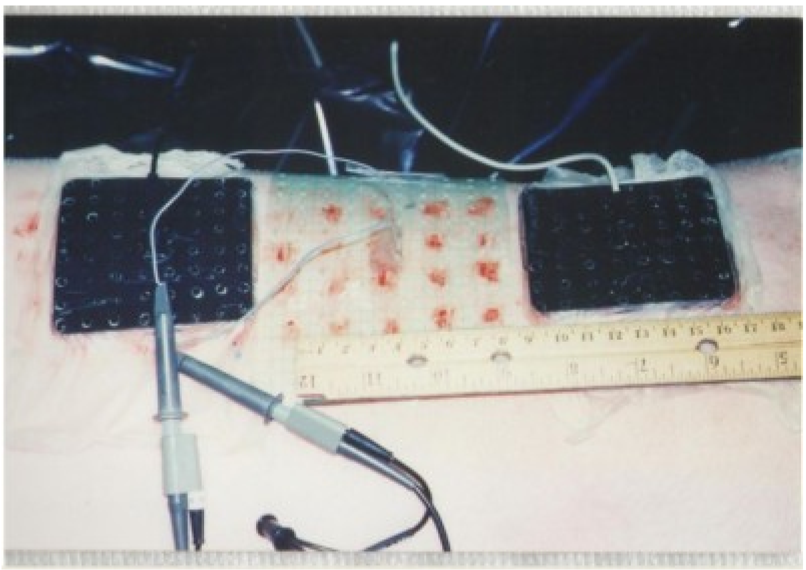

Illustration 5

Figure 5. An oscilloscope image of three typical waveforms measured in vivo potential differences (voltages) between two points in pig wounded skin with a 4 electrode system at an animal level, see Figure 4 and the text.

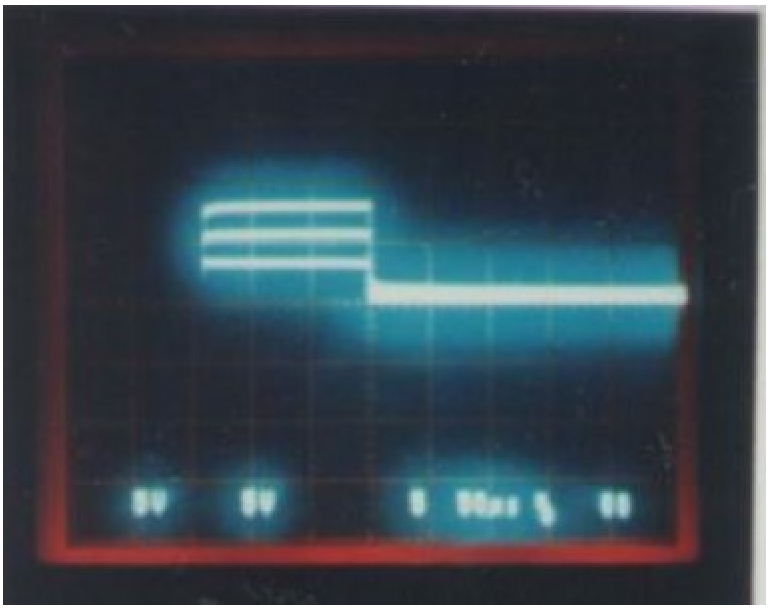

Illustration 6

Figure 6. Our model of meridian channel in vivo skin under a noninvasive conforming electrode, the meridian channels are mostly consist of sweat and sebaceous glands or wounds, see the text. The draw is not to the scale.

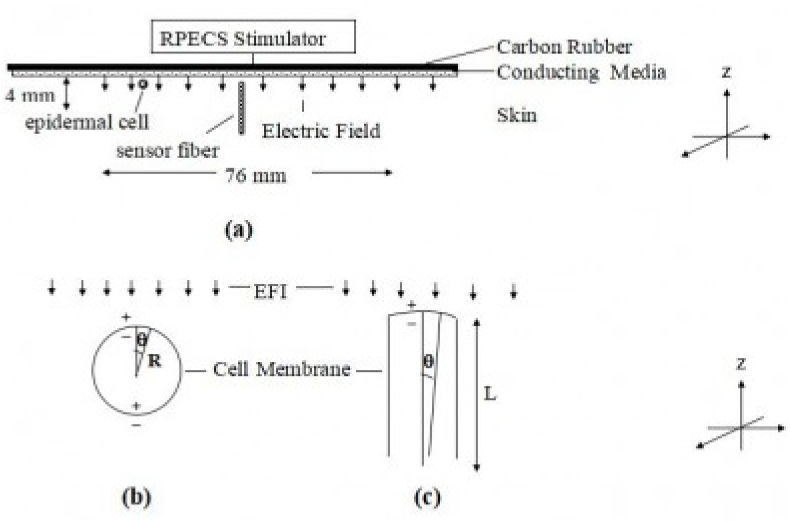

Illustration 7

Figure 7. Our model of functions of meridian channels with noninvasive RPECS in vivo tissues, see the text. The draw is not to the scale.

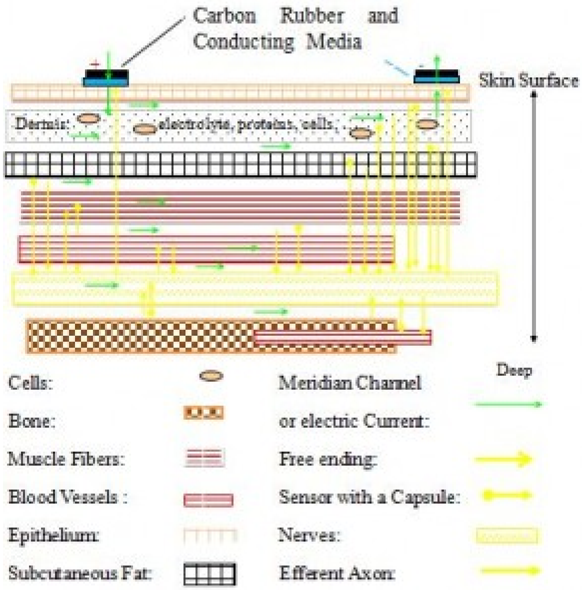

Illustration 8

Figure 8. The cut wound and drainage on day 10 (The base is 0.)

Illustration 9

Figure 9. Day 31, the cut wound, see the text.

Illustration 10

Figure 10. Our treatments of the pain control and wound healing with noninvasive RPECS, see the text.

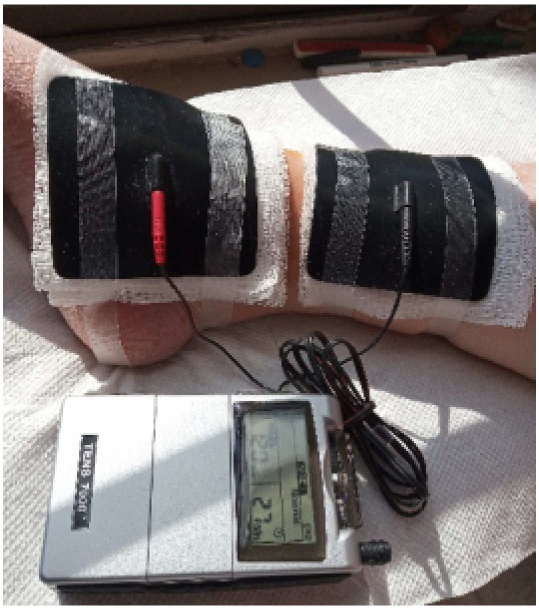

Illustration 11

Figure 11. Cut wound healing result, one day after noninvasive RPECS treatment, i.e., day 32 post diagnosis, see the text

Illustration 12

Figure 12. The wound healing result on day 11 after RPECS treatments, i.e., day 42 post diagnosis, see the text.

Illustration 13

Figure 13. The completely healed wound, a rule and forceps in 6 months after wounding, see the text.