Investigating the safety of electroacupuncture with a *Picoscope*™

John W Thompson, Mike Cummings

Abstract

Our wish to know more about the paths taken by electrical currents in electroacupuncture (EA) with special reference to the heart, particularly in patients with an implanted pacemaker, prompted us to undertake this study. Using ourselves as subjects, we have developed a safe oscillographic method to detect, visualise and record the EA currents that avoids the use of equipment requiring mains electricity. After two trials with unsatisfactory equipment, we found that the newly developed model 3425 *PicoScope*™ (Pico Technology Ltd), with a four channel differential amplifier input connected to a laptop PC operating in battery mode, satisfied our criteria. With this recording system, we carried out two sets of experiments in which EA was provided by a Cefar *acus4*™ stimulator. The results confirm that the placement of a pair of acupuncture needles for EA can be used to predict the paths taken by the stimulating currents, and thus their areas of likely influence. When the needles are placed in closely adjacent acupuncture points in a limb, there is little or no detectable spread of the currents along the limb or into the chest. By contrast, when the needles are placed far apart, the electrical currents spread widely. Thus, when each of a pair of needles is placed in a point on opposite arms, the electrical currents recorded in the area of the pectoral muscles is of an order that might trigger an abnormal cardiac rhythm in a susceptible heart or activate a cardiac pacemaker incorporating an intracardiac defibrillator (ICD). Our results confirm the guidelines for EA safe practice recommended by the British Medical Acupuncture Society (BMAS) to avoid adverse events, ie EA should not be applied such that the current is likely to traverse the heart. We can now be confident that electric fields generated by pairs of needles below the knee or elbow do not create detectable currents in the chest. It is likely that similar results would be obtained with the use of transcutaneous electrical nerve stimulation (TENS) but this remains to be established by additional experiments.

Keywords

Acupuncture, CEFAR acus4™, cardiac pacemaker, electroacupuncture, electrical currents, electrical interaction, electrical stimulation, laptop PC, oscilloscope, PicoScope™, adverse events.

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Introduction

Our wish to know more about the paths taken by electrical currents in electroacupuncture (EA) with special reference to the heart, particularly in patients with an implanted pacemaker, prompted us to make this study. In order to achieve this aim, we set out to develop a safe method to detect, visualise and record EA currents that avoided the use of equipment requiring mains electricity. This paper describes briefly the development of the method and then presents the results we obtained using ourselves as the subjects. This work was presented in a preliminary form to the Spring 2008 meeting of the BMAS in York.[1]

Methods

Basic approach

Our basic approach was to apply EA to one pair of acupuncture points (via a pair of needles) and to detect and record the currents so produced in a second pair of acupuncture points (via a second pair of needles). By this means we hoped that the paths of the EA-induced currents could be mapped out.

Required specification

We required (1) a recording system that could be connected to a human subject or patient to detect, visualise and record small currents or voltages induced by an EA stimulator; (2) a system that would be safe and without risk of shock from the electric mains; and (3) a portable system that could be used in the clinic.

Development

A suitable EA stimulator in general use by acupuncturists would be the Cefar *acus4*™. An obvious choice for the recording system would be an oscilloscope, but the disadvantage is that the majority of oscilloscopes operate from mains electricity and therefore are unsafe to connect to human subjects or patients. One possibility would be to use a battery operated oscilloscope but unfortunately these are not readily available. While searching for a suitable oscilloscope, one of us (JWT) was in contact with Dr Alex Macdonald who kindly sought advice on this subject from his colleague, the late Mr Alan Friskney. The latter drew our attention to the *PicoScope*™ (PicoTechnology Ltd), a device that is designed to convert a PC into an oscilloscope that can be used primarily to test motor car engines. JWT contacted Mr Martin Keay of PicoTechnology Ltd for further information and found that the *PicoScope*™ was normally connected to and powered through the USB port of a PC. After further thought, we conceived the idea of connecting a *PicoScope*™ to a laptop PC operating in battery mode, thereby creating an oscilloscope that should be safe to use for humans and patients. In order to test our proposed system, PicoTechnology Ltd kindly loaned us a model 3224 *PicoScope*™. The *PicoScope*™ was connected to a laptop PC (belonging either to JWT or MC), but before we began any experiments, the safety of the combination was tested for us by Dr Frank McArdle, Medical Physics department, Freeman Hospital, Newcastle upon Tyne; it was approved to be safe for use with humans.

Preliminary experiments

In the course of developing the method, we carried out a series of experiments on ourselves as follows.

Experiment 1 A pair of stimulating needles inserted into the tissues was connected to a Cefar *acus4*™ EA stimulator, and the output was monitored by connecting it to one channel of the Model 3224 *PicoScope*™; this was **the stimulating circuit**. A second pair of needles inserted into the tissues was used as a probe to detect the electrical currents induced in the tissues by the stimulating circuit and this was connected to a second channel of the *PicoScope*™; this was **the recording circuit**. However, it was soon apparent that this system would not work because, much to our surprise, the recording circuit also acted as a stimulating circuit. The reason it failed became clear when we discovered that the two input channels of the 3224 were not isolated but instead shared a common pole. This design feature, which was not mentioned in the specification of the Model 3224 *PicoScope*™, caused the recording needles to act as a second pair of stimulating needles! We therefore abandoned this experiment. After further thought we realised that the solution to this problem would be to connect the stimulating and recording circuits to two independent channels of a differential amplifier. We asked Pico Technology Ltd whether they produced such an instrument but they informed us then that they neither had such an instrument nor planned to develop one. So we continued to search for a suitable oscilloscope.

Experiment 2 Further searches led us to the Powerlab amplifier which incorporated differential amplifiers and initially appeared suitable. Mr Stephen Jones and Dr Arnaud Gac of AD Instruments Ltd, generously loaned us a Powerlab amplifier with oscilloscope (approved for human use) to which we connected the stimulating and recording circuits in the same way as for experiment 1. Unfortunately this system failed because the processing circuits of this amplifier did not operate satisfactorily with our stimulating and recording circuits. We halted our experiments and resumed our search for a suitable differential amplifier and oscilloscope.

Experiment 3 About a year after Experiment 2, we were pleasantly surprised to be contacted by PicoTechnology Ltd with the news that they had developed the *PicoScope*™ 3425 which incorporated four independent input channels each with a differential amplifier. Mr Martin McKeay generously offered to loan us an instrument and we connected our stimulating and recording inputs to two of the four channels of this instrument as for Experiment 1. Satisfactory recordings were obtained during which we were able to demonstrate the influence of needle positions on the interaction between the stimulating and recording circuits.

System finally adopted

From the results and experience obtained with Experiment 3, we were able to draw up the five components of the system that we finally adopted (Fig 1):

1.The EA stimulator (Cefar *acus4*™)
2. The stimulating & recording needles (Seirin 0.25 x 40mm with metal handle)
3. A connecting and switching box with dummy load (1kΩ resistor shunted by a 10kΩ resistor in series with a 10nF capacitor)
4. The *PicoScope*™ 3425 (powered through the connector lead inserted into a USB socket of item 5.)
5. The Laptop PC operating in battery mode.

Item 3 is required for two reasons: (1) in order to accommodate the heavy cables that terminate with large crocodile clips supplied with the *PicoScope*™ 3425 and (2) to act as a multichannel junction box between the crocodile clips and the miniature plugs, sockets and leads used to connect the *PicoScope*™ to the stimulating circuit (= EA stimulator + one pair of acupuncture needles or dummy load) and the recording circuit (= second pair of acupuncture needles).

Using the system described above, Experiment 3 was replicated and is named Experiment 4, the results of which are described below. For this set of experiments the following conditions applied: the stimulating and recording needles used were Seirin 0.25 x 40mm (with metal handle) inserted to approximately 20mm depth. EA was carried out by connecting the pair of stimulating needles to a single channel of a Cefar *acus*4™ stimulator set to 2 Hz frequency with pulse width of 180 µsec (programme 2) at current intensity of 5mA (maximum current obtainable 12mA). The acupuncture points used are described in the text below. Recordings were made from six different sets of positions (A, B, C, D, E, F) of the stimulating

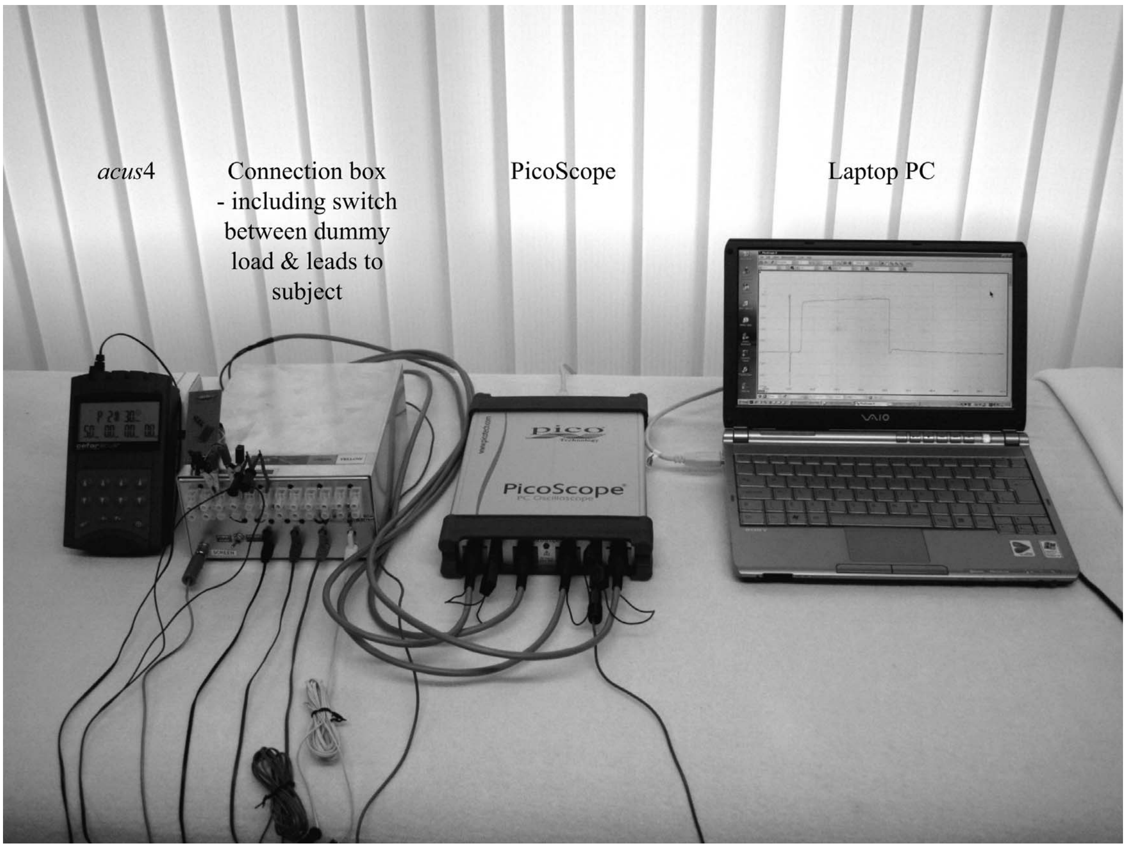


Figure 1 This is a photographic image of the equipment used in Experiment 4.

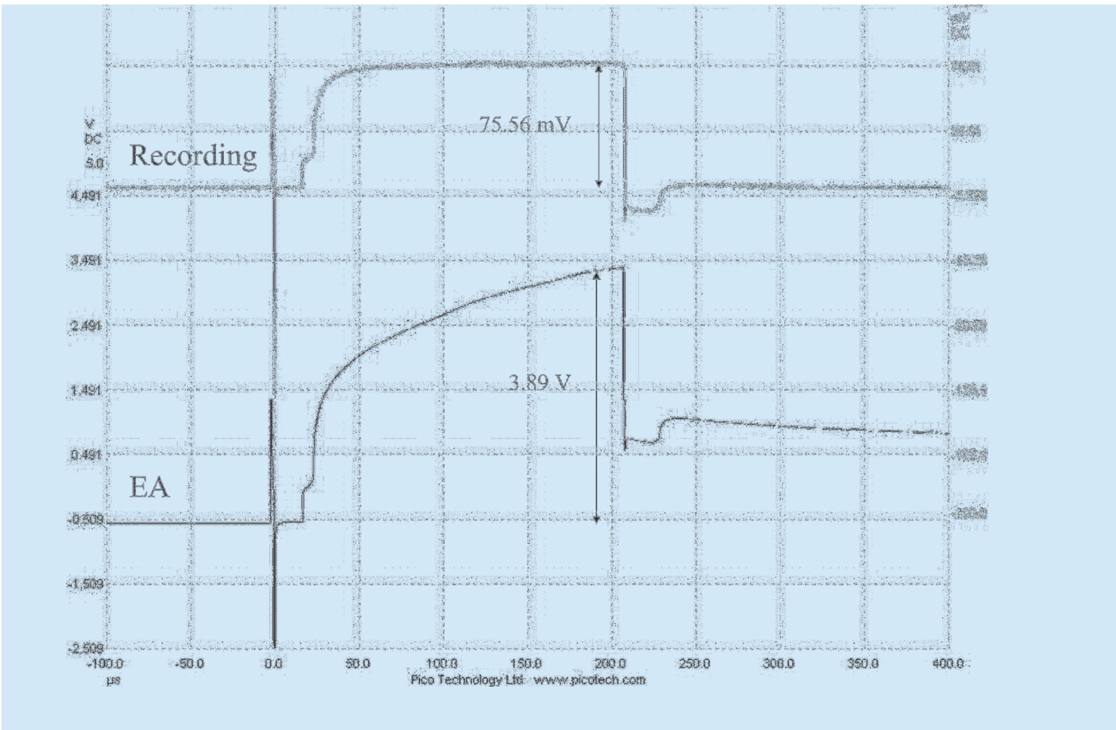
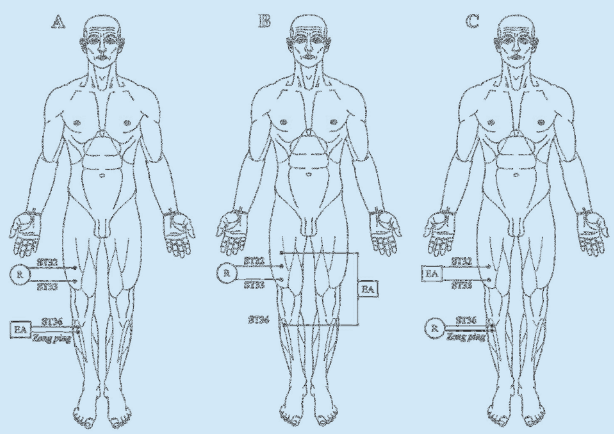
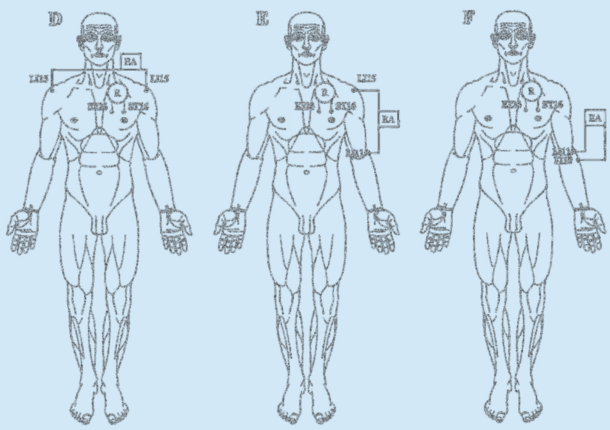


Figure 2 This is an example of a still image recorded from the PicoScope™ during one of the experiments (Experiment 4B). The upper tracing is from the recording needles and the lower tracing is from the stimulating needles. The right axis (in millivolts) relates to the upper trace, and the left axis (in volts) relates to the lower trace.



Stimulating needles (V)	**3.47**	**3.89**	**3.97**
Recording needles (mV)	**<1.0**	**75.56**	**<1.0**
Recording mV per EA volt	**<0.29**	**19.42**	**<0.25**

Figure 3 The diagram illustrates the positions of the pairs of stimulating (EA) and recording (R) needles and their connections used in Experiment 4A, B and C. The tabulated results are included beneath the relevant part of the experiment, and include the amplitude of the waveform recorded with the PicoScope™ across the stimulating needles (upper row), across the recording needles (middle row), and the ratio of the two measurements (lower row).



	D	E	F
Stimulating needles (V)	4.47	4.17	4.42
Recording needles (mV)	8.89	<0.77	<1.0
Recording mV per EA volt	1.99	<0.18	<0.23

Figure 4 The diagram illustrates the position of the pairs of stimulating (EA) and recording (R) needles and their connections used in Experiment 4D, E and F. The tabulated results are included beneath the relevant part of the experiment, and include the amplitude of the waveform recorded with the PicoScope™ across the stimulating needles (upper row), across the recording needles (middle row), and the ratio of the two measurements (lower row).

recording needles (Figure 2 is an example of a recording; Figures 3 and 4 show electrode positions).

Results

Figure 2 illustrates a recording of the results of one of the parts of Experiment 4. The results for each of the parts were taken from images captured from the *PicoScope*™. The full results are presented in Figures 3 and 4.

Experiment 4A (Figure 3)

With the stimulating needles (EA) placed in the right leg at ST36 and *Zong ping* (extra point one cun below ST36), while the recording needles (R) were placed at ST32 & ST33, <0.29mV per EA volt was detected by the recording needles.

Experiment 4B (Figure 3)

In this experiment the stimulating needles were straddled across the recording needles. Thus, the stimulating needles (EA) were placed in the right leg at ST36 and at a point just above ST32, while the recording needles (R) remained at ST32 & ST33, as in Experiment A. Under these conditions, 19.42mV per EA volt was detected by the recording needles, namely nearly 70 times that recorded in experiment A.

Experiment 4C (Figure 3)

In this experiment the positions of the needles were restored to those used in experiment A but the connections were transposed. Thus, the proximal pair (ST32 and ST33) were used as stimulating needles, while the distal pair (ST36 and *Zong ping*) were used as recording needles. These transposed connections were carried out in order to test simultaneously for reproducibility of effect that is independent of current direction. In this case, <0.25 mV per EA volt was detected by the recording needles, a value highly consistent with that found in experiment A.

Experiment 4D (Figure 4)

With the stimulating needles (EA) placed in the anterior shoulders bilaterally at LI15 while the recording needles (R) were placed over the left pectoral region in KI24 and ST16, 1.99 mV per EA volt was detected by the recording needles.

Experiment 4E (Figure 4)

With the stimulating needles (EA) placed unilaterally in the left anterior shoulder and left elbow at LI15 and LI11, respectively, while the recording needles (R) remained in the left pectoral region at KI24 and ST16, <0.18 mV per EA volt was detected by the recording needles.

Experiment 4F (Figure 4)

With the stimulating needles (EA) placed unilaterally in the left elbow and forearm at LI11 and L10, respectively, while the recording needles (R) remained in the left pectoral region at KI24 and ST16, <0.23mV per EA volt was detected by the recording needles.

From these results it may be concluded that when the stimulating and recording needles are placed in closely adjacent acupuncture points in a limb, there is little or no detectable spread of electrical current along the limb and consequently very little transfer of electrical current or voltage between them. By contrast, when the needles are placed far apart, particularly when the stimulating needles straddle the recording needles, either in a limb or in the chest, a significant amount of electrical current or voltage is transferred between the two sets of needles.

Discussion

Compared with manual acupuncture, EA carries additional inherent risks due to the use of electricity. For EA it is common practice to use electrical currents of the order of several milliamperes (mA) and usually these have proved safe. Nevertheless there are reports of potentially adverse interactions in patients with cardiac pacemakers who were receiving EA. Thus, Fujiwara *et al* (1980)[2] reported interference with a demand pacemaker by low frequency EA employed for anaesthesia during neck surgery (parathyroidectomy). 'The active needle electrodes were punctured at the ears, lateral cervical areas, right leg and arm, and an inactive plate was placed on the upper abdomen. The direct current across each electrode was estimated to be about 3mA.' Apparently this interaction was observed during routine electrocardiography although fortunately no adverse clinical effects were reported. More recently, Lau *et al* (2005)[3] reported a patient with an implanted intracardiac defibrillator (ICD) in whom EA triggered inappropriate shocks in the presence of normal sinus rhythm. The stimulating needles had been inserted into the anterior chest. Fortunately this patient 'suffered no long term sequelae from the experience.' Nevertheless, in both these patients and others in similar circumstances, serious and potentially fatal outcomes could occur.

The BMAS has laid down certain guidelines for safe practice with EA[4;5] based on an interpretation of existing knowledge, and one of the main aims of this study has been to provide evidence to support these proposals. The results presented above confirm that, with appropriate placement, EA can be applied so that the current is not likely to traverse the heart, and thus confirm the BMAS guidelines. The results also illustrate that electric fields generated by pairs of needles placed below the elbow or knee do not create detectable currents in the chest. A key principle that should always be borne in mind when deciding upon the placement of stimulating needles for EA is to consider where the electrical currents are likely to flow. If these are likely to cross the heart, then this placement is prohibited.

The results of this study also support the view that it is potentially dangerous to use EA in a patient with an implanted ICD. If this were to be attempted, then the inappropriate triggering of the ICD by EA could cause a serious or fatal arrhythmia. By contrast, the use of EA in a patient with a pacemaker that does not contain an ICD is usually safe,[6] although when in doubt, the patient's cardiologist should be consulted before proceeding with EA treatment.

Similar problems can arise with the use of transcutaneous electrical nerve stimulation (TENS). It seems most likely that using the recording system described in this paper, similar results would be obtained with TENS but this needs to be established by additional experiments; these are planned.

Conclusion

Our results confirm the guidelines for EA safe practice recommended by the BMAS,[4;5] ie EA should not be applied such that the current is likely to traverse the heart. We can now be confident that electric fields generated by pairs of needles below the knee or elbow do not create detectable currents in the chest.

Summary points

This series of experiments confirms that the placement of a pair of acupuncture needles for EA can be used to predict the path taken by the stimulating current, and thus the areas of likely influence

EA should not be applied such that the current is likely to traverse the heart

When the needles are placed in closely adjacent acupuncture points in a limb, there is little or no detectable spread of the currents along the limb or into the chest

The use of EA with pairs of needles in limb points is likely to be safe in patients with pacemakers, but this advice cannot be applied to patients with intracardiac defibrillators without further safety studies, and if there is any doubt, the patient's cardiologist should be consulted before embarking on treatment

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Conflicts of interest

The authors declare no conflict of interest.

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