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Kinetics of the effect of the auricular heart point on the pressure-volume curve of the digital pulse

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Abstract

Introduction: The Heart auricular point has been shown to modify the characteristics of the digital pulse wave experimentally. However, kinetic studies have yet to widely evaluate its cardiovascular effects. The objective of this study was to propose an acukinetic model of the Heart auricular point effect using polynomial linear interpolation or spline.

Methods: The digital volume pulse was recorded in healthy subjects. A photoplethysmography transducer was placed on the index finger of the right hand. The signal was modulated and amplified using the MP150 amplifier processor. A continuous 70-s recording was taken consisting of a 30-s baseline (1–30 s), a 10-s transacupuncture (31–40 s), and a 30-s post acupuncture periods (41–70 s). Participants received acupuncture at the Heart point of the right ear. The needle was inserted to a depth of approximately 3 mm, with no additional stimulation; and remained inserted for 10 s. Derivatives and integrals of each pulse cycle during transacupuncture periods were solved. The peak slope values and area under the curve of the transacupuncture period were used to construct an interpolated curve.

Results: Analysis of spline curves during the transacupuncture period showed a decrease in their values in the initial period of auriculopuncture stimulation, with a recovery in the second part. These results may indicate that auriculopuncture initially reduced cardiac output, possibly causing a secondary sympathetic response mediated by baroreceptors.

Conclusion: These results may indicate that auriculopuncture initially reduced cardiac output, possibly causing a secondary sympathetic response mediated by baroreceptors.

Keywords: Auricular point Heart; Photoplethysmography; Cardiovascular physiology; Digital volume pulse

1. Introduction

Advances in biomedical knowledge now allow us to understand the mechanisms of the changes that acupuncture produces in the body [1–3]. Auricular acupuncture has been reported to improve hypertension and other cardiovascular disorders [4, 5]. It has been shown that heart rate variability, systemic vascular resistance, and other variables are modified with the application of auriculotherapy [6]. In particular, the Heart point on the ear is used in patients with hypertension [7]; it modifies the indices of the acceleration photoplethysmogram [8]. The Heart point is in the center of the concha cavum of the ear; see Figure 1 [9]. Nonetheless, the kinetics of the effect of auriculopuncture on Heart point has not been assessed.

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Figure 1 Auricular Heart point

Photoplethysmography is a noninvasive device for detecting changes in blood volume by optical means. It was first described by Hertzman [10]. Photoplethysmography results in acquiring the digital volume pulse (DVP) [11]; see Figure 2. The polynomial linear interpolation or spline is a suitable method to propose a kinetic model of the effect of auriculopuncture in Heart point.

Our study aimed to develop a kinetic model of the effect of the auricular Heart point on the digital pulse curve in healthy subjects.

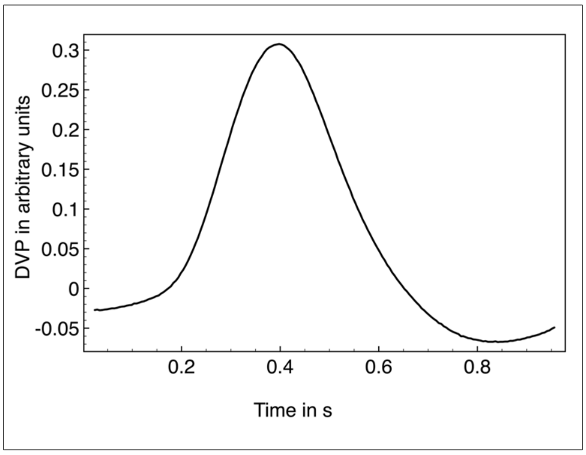

Figure 2 Digital volume pulse curve

The DVP contour results from an interaction between the left ventricle function and systemic circulatory compliance (Figure 2). This contour features an early systolic peak and a late peak or inflection point that occurs shortly after the first peak at the beginning of diastole.

1.1. Derivation and integration of cycles of the DVP curve

The derivation and integration of each circulatory cycle of the DVP curve over a period allows us to analyze the physiological characteristics of isolated circulatory cycles. The rate of change of a function, the DVP, is evaluated by its derivative; conversely, the accumulated discrete values of a function over a series of values can be estimated by the integral.

Integrals are used in various fields, including measuring distance, area, volume, and work. For example, the work done by a variable force or fluid dynamics can be calculated using integrals. The area under the VPD curve medically represents the cardiovascular work during each cycle of the vascular pressure-volume variation during each heartbeat.

1.2. Polynomial linear interpolation and area under the curve of DVP cycles

The kinetic behavior of pressure-volume changes following acupuncture stimulation can be evaluated by constructing a curve using polynomial linear interpolation or spline and representing a model of physiological behavior.

Thus, the purpose of this research is to analyze the kinetics of the Heart point effect on the pressure-volume of the DVP and propose an acukinetic model of physiological behavior using polynomial linear interpolation or spline.

2. Population and Methods

2.1. Study design and setting

A cross-sectional experimental kinetic study was conducted at the Faculty of Nursing, Autonomous University of the State of Morelos, México.

2.1.1. Population

All subjects in this study were healthy volunteer students from the Faculty of Nursing, Autonomous University of the State of Morelos, Cuernavaca, Mexico. These subjects were recruited by using flyers. Three healthy subjects of either sex aged 35-40, non-smokers, with no clinical data of cardiovascular disease, obesity, sports training, or having received medication or acupuncture treatment in the ten days before the study were included.

2.1.2. Ethical aspects

The Ethics Committee of the Division of Biological and Health Sciences approved this study, which conforms to the principles of the revised version of the Declaration of Helsinki [12]. Subjects were provided an explanation of the study, and written informed consent was obtained.

2.1.3. Digital volume pulse (DVP) recording

A photoplethysmography transducer (BIOPAC Systems, TSD200) was placed on the index finger of the right hand. This transducer transmits infrared light at 860 ± 90 nm to obtain a DVP recording. The photoplethysmograph frequency reply was flat at 10 Hz. An analog-to-digital converter with a sampling rate of 200 points per second was used to record the digital output of the photoplethysmograph (BIOPAC Systems, MP150) and the use of analysis platform provided by AcqKnowledge v. 4.0 software. A 70-second recording were obtained from each participant (Figure 3).

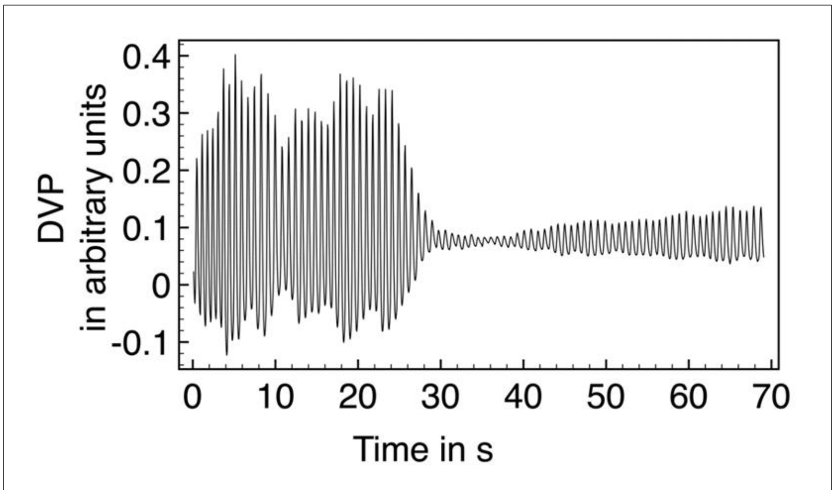

Figure 3 Characteristic record of the digital volume pulse (DVP) during the 70 s register period

2.2. Calculation of the derivative of the digital volume pulse

The exact onset of the DVP was calculated using the first derivative of the DVP obtained with Plot2 software v. 2.5.15 (Micw.org, USA), Figure 4.

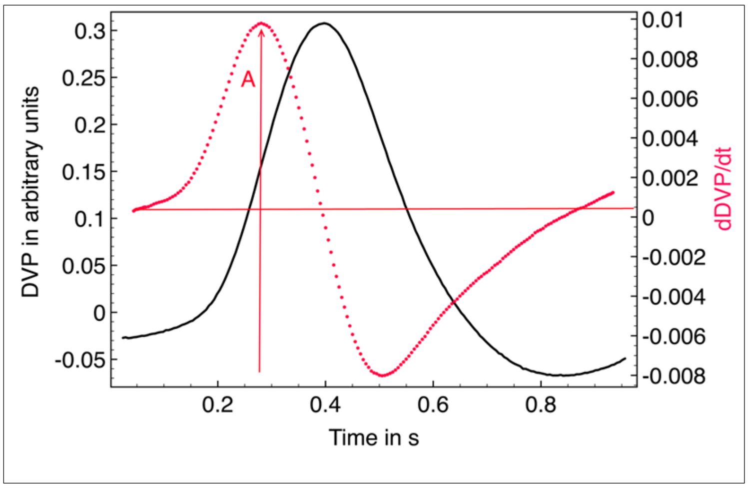

Figure 4 Digital volume pulse (DVP) and its first derivative (dDVP/dt). A= point of maximum speed of the systolic rise

2.3. Calculation of the area under the digital volume pulse (DVP) curve

Various methods can be used to calculate the area under a DVP cycle curve. Integration is the most common method for determining the area within two defined limits of a continuous curve (Figure 5).

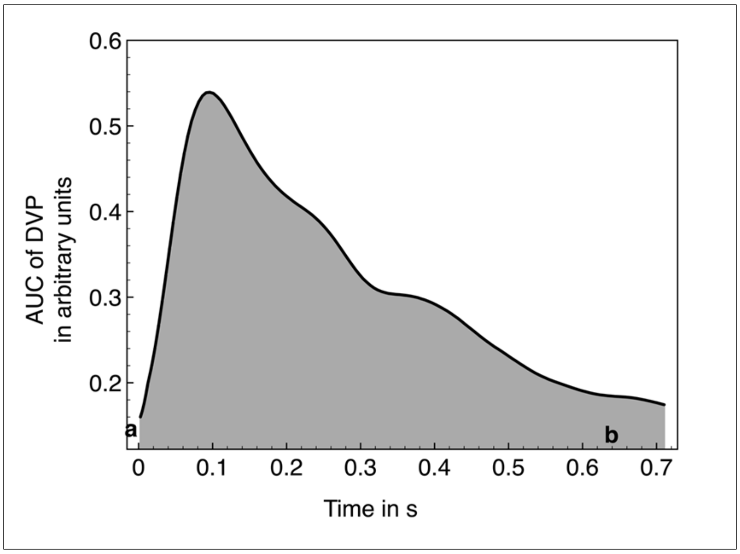

Figure 5 Area under the curve (AUC) of a digital volume pulse cycle

2.4. Riemann sum method integrated the area under the curve for each DVP cycle

This method involves taking small curve sections and equating each section to a rectangle. For each rectangle, the height is equal to the value of the function at that point, and the width is equal to the length of that small section of the curve. This process is repeated until the entire area of the curve is covered. The Riemann sum was performed using the Plot2 web application (v.2.6.15, 2019 micw.org), and the function and integration limits were entered on the x-axis, see Figure 6.

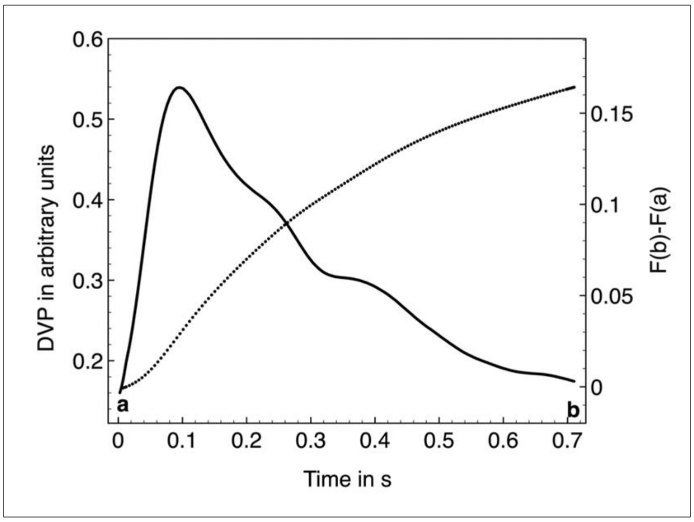

Figure 6 Digital volume pulse (DVP) and integral of digital volume pulse F(b)-F(a)

2.5. Polynomial linear interpolation or spline

The maximum values of each cycle of the derivatives were taken to analyze the kinetics of the effect of the Heart point by using polynomial linear interpolation, and regarding the integrals, the values of the total area of each cycle for the 31-40 s period of each recording were taken.

2.6. Auricular acupuncture treatment

Manual acupuncture was applied without additional electrical or laser stimulation at the auricular point Heart, Figure 1. According to standard auriculotherapy texts, the Heart point was located on the ear using anatomical references [13]. The needle was inserted perpendicular to the skin plane at a depth of 2 mm for 10 seconds. Sterile 13 mm, 0.22 mm acupuncture needles with a silver handle (Seirin Corporation, Shizuoka, Japan) were used.

2.6.1. Practitioner background

A physician with more than one year of acupuncture experience performed all acupuncture stimuli.

2.6.2. Study Protocol

Measurements were performed after a 4-hour fasting period. During the study, subjects remained in a sitting position. After recording their clinical information, all subjects were at rest for 10 minutes before the recordings began. Measurements were taken between 16:00 — 19:00 p.m. to standardize conditions concerning cardiovascular circadian variations. After the resting period, a digital photoplethysmograph was placed on the index finger of the right hand of each subject. After a baseline recording period of 30 seconds, acupuncture was applied to the Heart point of the right auricle starting at the 30th second of the recording for 10 seconds; after the needle was removed, the DVP recording was continued until 70 seconds was completed.

2.6.3. Comparisons

The recordings of each subject during the study periods were plotted using the Plot2 application, v.2.6.15 (Michael Wesemann, Berlin, Germany, 2019). The following parameters were compared:

- The values of the slopes for the transacupuncture recording period 31 — 40 s.
- The values of the integrals for the areas under the curve of each cycle during the same recording period 31 — 40 s
- The polynomial linear interpolation curve of the maximum values of slopes and areas under the curve of the period corresponding to the cycles during the stimulation period with auriculopuncture, 31 - 40 s.

The interpolated data from 3 subjects for the same study periods, i.e., 31–40 s, were averaged.

3. Results

3.1. Polynomial interpolation (spline) of the systolic slope values

The polynomial interpolation or spline interpolation corresponding to the maximum values of the systolic slopes during auriculopuncture stimulation, 31 – 40 s of the Heart point, are shown in Figure 7.

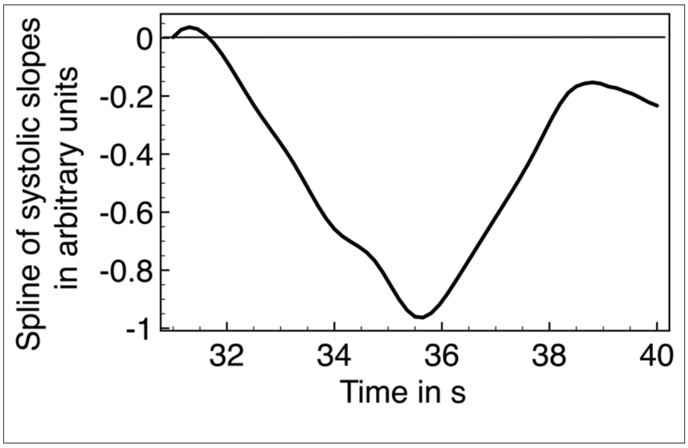

Figure 7 Polynomial linear interpolation or spline of the variations of the systolic slopes of the 31 – 40 s period of the recording period

3.2. Polynomial linear interpolation or spline of the values of the areas under the curve

Figure 8 shows the polynomial linear interpolation or spline interpolation corresponding to the values of the areas under the curve during the period of stimulation with auriculopuncture, 31 – 40 s of the Heart ear point.

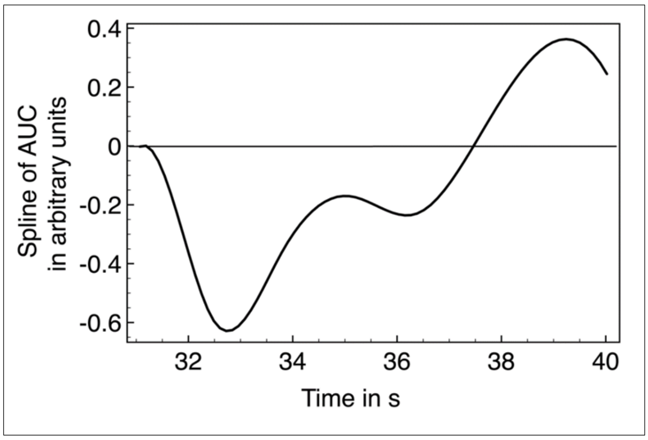

Figure 8 Polynomial linear interpolation or spline of the area variations under the curve (AUC) of the 31 – 40 s period of the registered period

4. Discussion

The main findings of this kinetic study were that manual stimulation of the Heart point of the right ear produced a biphasic effect during the auriculopuncture period (31-40 s) - with an initial decrease in the values of the slopes and the areas under the curve with a subsequent recovery towards the basal values.

Regarding the methods used, photoplethysmography is a simple method to obtain a digital volume pressure (DVP) curve. The DVP results from the interaction of two main variables: the effectiveness of cardiac contraction and the degree of distensibility of the arterial system, mainly related to large and medium arterial vessels. The physicalphysiological components of the DVP pressure-volume curve can be analyzed mainly through derivation and integration processes.

Integrals are used in various fields, including measuring distance, area, volume, and work. For example, the work done by a variable force or fluid dynamics can be calculated using integrals. The area under the DVP curve represents the cardiovascular work during each cycle of the vascular pressure-volume variation consecutive to each heartbeat. Integration will allow us to analyze the component areas of the DVP. Obtaining the area under the curve of the DVP cycle by the Riemann sum is a method that allows us to get closer to estimating the actual area, which is the integral.

In this way, analyzing the maximum slopes using the derivation of the DVP curve provides information about the speed of pressure changes during the arterial pressure-volume cycle. The pressure-volume changes in each cardiovascular cycle are related to the effectiveness of cardiac contraction and the degree of distensibility of the arterial system, especially of the large vessels.

On the other hand, integrating the area under the curve of each DVP cycle allows information to be obtained about the work performed during the different phases of the circulatory cycle. The work developed during the variations of the pressure-volume curve is directly related from the physiological and clinical point of view to the balance of consumption and availability of oxygen for cardiac work.

4.1. Area components of the pressure-volume curve in each DVP cycle

The initial slope of vascular filling corresponds to the effectiveness of ventricular systole and the initial arterial resistance. It can be extrapolated by calculating the value of the integral corresponding to the area of the systolic start at the maximum value of systolic pressure. On the other hand, the total value of the integral corresponding to a cycle corresponds to the cardiac and vascular work involved in each cycle of the DVP.

Polynomial linear interpolation or spline. In mathematics, a polynomial interpolated curve or spline is a function defined piecewise by polynomials. Interpolation or spline is achieved by using polynomial theory. Interpolated curves are standard in design and biomedicine due to the simplicity of their construction, the ease and precision of their evaluation, and ability to approximate complex shapes through curve fitting related to drug behavior.

It is proposed that the levels and phases of functional response to acupuncture can be analyzed by interpolated curves, creating acukinetic models.

4.2. Effects of the Heart point on the pressure-volume curve of the DVP

Previous results from this same group showed that stimulation of the Heart point on the ear initially decreased heart rate, stroke volume, and cardiac output with a secondary increase in peripheral vascular resistance [14]. These authors propose that the increase in peripheral vascular resistance was a secondary response to the reduction in cardiac output. Other reports from human studies show that acupressure on the Heart point significantly reduces heart rate in healthy volunteers [15]; needling on the auricular Heart point also reduces heart rate in athletes [16]. Furthermore, in experimental animal models, the Heart point on the ear produces a decrease in heart rate and blood pressure; the authors suggest that this effect is related to the activation of sensitive neurons associated with the activity of arterial baroreceptors in the solitary tract nucleus [17].

Accordingly, experiments with auricular point stimulation produced decreased stroke volume and heart rate that may be related to increased vagal activity or decreased sympathetic activity [16, 17, 18].

5. Conclusion

From the results of this study and previous studies of this group, the following conclusions can be drawn regarding the action of the auricular point Heart. The stimulation of this point causes initial cardiovascular effects that result in a decrease in the rate of increase in arterial volume and a compensatory response of the organism. The experimental results of this study support the need to perform kinetic analysis of interventions with various body acupuncture and auriculotherapy points used in the treatment of various cardiovascular disorders. Kinetic analysis may allow the proposal of mechanisms of action of acupuncture points and improve their clinical use.

Polynomial linear interpolation proved to be a valuable tool for proposing a kinetic model of the action of the Heart auriculotherapy point. This kinetic study suggests the existence of a sequence of primary changes originated by the action of the Heart point and secondary organic responses. From the results of this study, the following conclusions can be drawn regarding the action of the auricular point Heart. The stimulation of this point causes initial cardiovascular modifications to decrease the rate of arterial volume increase and secondary compensatory response. These results support the need for kinetic analysis of interventions with a body and auricular acupuncture points to treat cardiovascular disorders. Kinetic analysis may allow for clarifying the mechanisms of action of acupuncture points and improving their clinical use.

Compliance with ethical standards

Acknowledgments

We are indebted to M.Sc. Beatriz Lisbeth Rodríguez Bahena, Director of the Faculty of Nursing of Autonomous University of the Morelos State, México.

Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Statement of ethical approval

This study was performed following the ethical principles for medical research involving human subjects of the Declaration of Helsinki [12].

Statement of informed consent

The protocol, including the informed consent document, had approval from the Institutional Ethics Committee of the Universidad Autónoma Metropolitana. All participants agreed to participate in the study, received detailed information about the purpose of this investigation, and signed an informed consent document.

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