

Research Paper

Thermal Effects of Acupuncture by the Infrared Thermography Test in Patients With Tinnitus



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Abstract

Previous studies have confirmed the efficacy of acupuncture treatment for tinnitus. However, no relevant studies of the exact mechanism of acupuncture efficacy on tinnitus have been published. Enrolled participants with left-sided tinnitus received acupuncture treatment at TE3 and TE5. The acupuncture session lasted for 30 minutes. The infrared thermography (IRT) test of each participant's bilateral aural regions and visual analog scale scores were taken before and after the first acupuncture treatment session. Fifty-four participants accepted acupuncture treatment and the IRT test. The temperature differentials of both sides were reduced significantly, but the maximum, minimum, and average temperature of bilateral aural regions did not have a significant difference before and after acupuncture session. The acupuncture's effects for tinnitus were associated with the improvement of cochlear blood flow via the IRT test. We have planned a full-scale randomized controlled trial to find out more about the underlying mechanisms of acupuncture for tinnitus.

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1. Introduction

Tinnitus is an otorhinolaryngological disorder that is defined as the sensation of sound without a corresponding external acoustic stimulus and classified as a phantom phenomenon. Tinnitus sensations sound similar to buzzing, hissing, or ringing. Tinnitus can be localized unilaterally or bilaterally, and most patients with tinnitus have unilateral problems [1]. In western Europe or the USA, the prevalence rates are between 10% and 15% of the adult population [2], which were similar to those in China [3], Egypt [4], Japan [5], and Nigeria [6] according to previous epidemiological studies, whereas the exact etiological factors of tinnitus are unclear and remain to be clarified.

Acupuncture is one of the therapies originating from traditional Chinese medicine (TCM) as well as complementary and alternative medicine in the Western countries, and it has fewer side effects than medications. The efficacy of acupuncture treatment for tinnitus was verified by randomized controlled trials [7-11]. Effective acupoints for tinnitus included GB2, SI19, TE21, TE3, and TE5 [12]. To clearly explain for the essential association between acupoint selection and the clinical effects, the underlying meridian mechanisms interconnected with physiopathological mechanisms of acupuncture should be found out. The lack of published evidence-based studies hinders the development of acupuncture treatment for central auricular system diseases.

Currently, more and more studies [13-15] reveal that cochlear blood flow abnormalities were negatively associated with tinnitus, and blood flow changes in the tissues or organs of living body could be monitored by thermal changes of body surface through infrared thermography (IRT) [16,17]. This pilot study was conducted to find out the possible mechanisms of acupuncture treatment for tinnitus by investigating cochlear blood flow changes via the instant IRT test on bilateral aural regions in a group of patients with unilateral tinnitus. Acupoints TE3 and TE5 were selected in our study because they are distant acupoints locating on the distal end of the triple energizer meridian (also called ear meridian) [18] that extends to the aural region according to the TCM classic meridian theory. These two acupoints are most frequently used for tinnitus owing to their effectiveness and high safety property by locating on upper limbs and avoiding damage to large vessels and lungs on the trunk of the body, and they can avoid the regional thermal disturbance from proximal acupoints around the aural region.

2. Materials and methods

2.1. Study design

The pilot study was designed as a preintervention and postintervention single-group design in patients with left-sided tinnitus. Enrolled patients were tested by IRT on bilateral aural regions shortly before and after the first session of acupuncture treatment to catch the instant thermal changes affected by acupuncture.

2.2. Recruitment

Posters were put up in the hospitals to inform patients and their family members of the recruitment of patients with left-sided tinnitus in the study. After signing the informed consent, all the participants received free acupuncture treatments and researchers' contact information.

2.3. Inclusion criteria

Patients were encouraged to take part in the trial if they met the following criteria:

- Are male or female, 18 years and older.
- Only have left-sided tinnitus based on the diagnostic criteria.
- Have not accepted any therapy in the recent one week.
- Willing to participate in the trial and sign the consent form.

2.4. Exclusion criteria

Patients were excluded from participating in the study if they met the following criteria:

- Have acoustic duct diseases, middle ear diseases, or symptomatic tinnitus resulting from cerebral trauma, diabetes, hypertension, or hyperthyroidism.
- Have severe cardiac, cerebrovascular diseases, renal diseases, or hematologic diseases.
- Have severe mental diseases, dementia, or cancers.
- Are prone to fainting.

2.5. Intervention

The acupuncture intervention was conducted by a licensed acupuncturist who has used acupuncture in his/her practices for at least 10 years and had treated at least 300 patients with acupuncture in the year before the trial. The chief investigator supervised the intervention process carefully. After skin sterilization, TE3 and TE5 on the left side were punctured 12 mm vertically into the skin by disposable silver needles of 0.25 mm × 40 mm. The needle was retained for 30 minutes. Needle manipulations were conducted to obtain *de qi* sensation. During the 30-minute treatment session, the room temperature was controlled in a closed room without air motion, direct sunlight, or other radiation source, and all the participants were informed to report any discomfort related to the acupuncture treatment.

2.6. Outcome measurement

2.6.1. IRT test

Temperature images of an individual's bilateral aural regions were captured by IRT before and after the first acupuncture treatment session. We took 10 seconds to capture 3 IRT images for analysis at one aural region at a time.

The participants were required to calm down for 10 minutes until their breathing and heart rate stabilized. IRT images were captured in a temperature-controlled room. The camera (Chongqing Associated Technology Co., Ltd., Chongqing, China) was a noncooled focal plane medical infrared imaging device with an image resolution of 384×288 , temperature resolution $\leq 0.08^\circ\text{C}$, and spatial resolution of 0.7 m rad. We selected 2×2 square centimeters around the auditory meatus for measurement through the analysis software (Chongqing Associated Technology Co., Ltd.).

2.6.2. Visual analog scale

The visual analog scale (VAS) determines the level of severity of tinnitus. It is a visual graphic tool to determine the intensity or discomfort caused by tinnitus with a scale of 0–10. The patient was asked to give a score from 0 to 10 according to the severity of tinnitus (0 for no symptoms and

10 for the worst symptoms). The VAS was measured before and after the 30-minute session for acupuncture treatment.

2.7. Data analysis

An independent statistician used SPSS 24.0 (SPSS Inc., Chicago, IL, USA) to conduct the whole data analysis. Not conforming to normal distribution, the continuous variables, presented as mean \pm standard deviation, were compared before and after acupuncture treatment by the rank sum test. A $p < 0.05$ was considered significant.

3. Results

Seventy patients with left-sided tinnitus were willing to take part in the clinical study, but only 54 participants met the eligibility criteria. Of these, 31 were women and 23

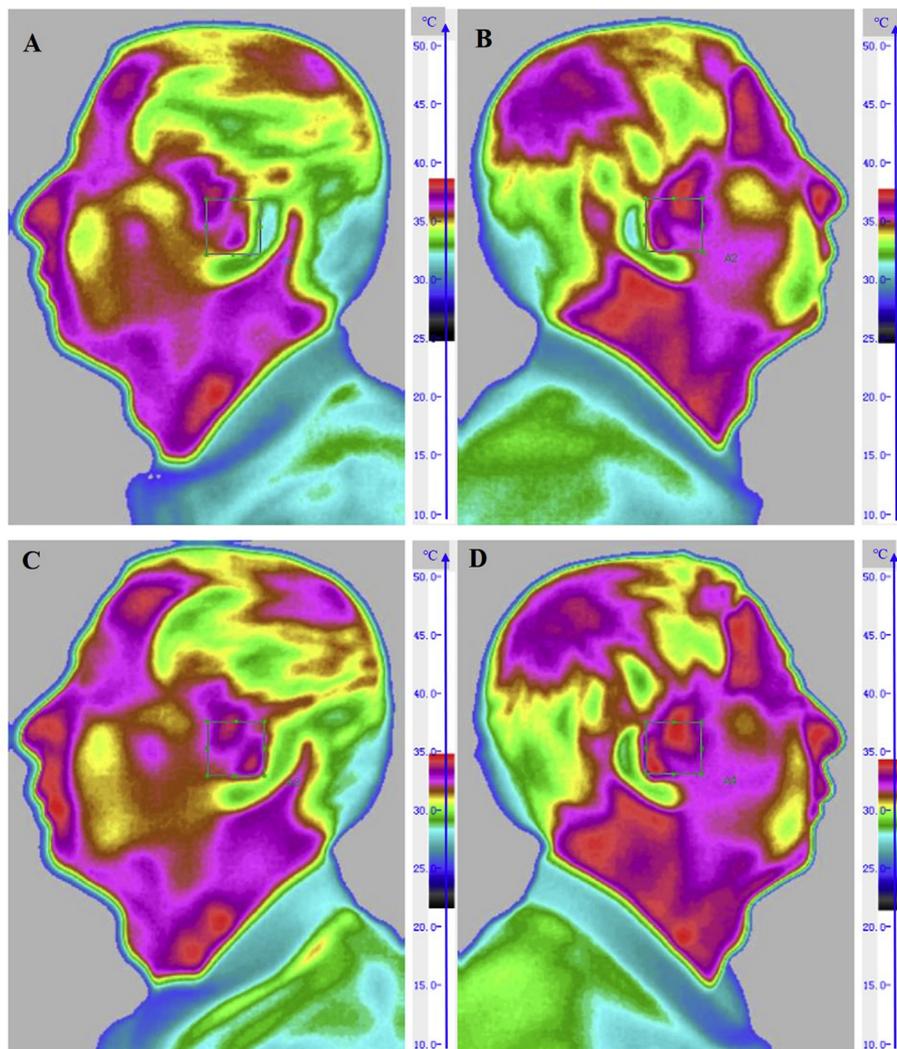


Fig. 1 An example of the infrared thermography (IRT) image of bilateral aural regions of patients with left-sided tinnitus. The brighter colors (red, orange, and yellow) indicate warmer temperatures, whereas darker colors (green, blue, purple, and black) indicate cooler temperatures. (A) The IRT image of the affected side before acupuncture treatment. (B) The IRT image of the contralateral side before acupuncture treatment. (C) The IRT image of the affected side after acupuncture treatment. (D) The IRT image of the contralateral side after acupuncture treatment. All the squared regions were external auditory meatuses that were selected for temperature testing.

Table 1 Regional square temperatures (°C) before and after acupuncture treatment at TE3 and TE5.

Item	Before	After	<i>p</i>
Temperature differentials of the affected side	2.75 ± 1.76	2.40 ± 1.13*	0.019
Temperature differentials of the contralateral side	2.93 ± 1.28	2.50 ± 1.23*	0.032
Maximum temperature of the affected side	34.89 ± 2.06	34.33 ± 0.78	0.985
Maximum temperature of the contralateral side	34.99 ± 2.15	34.35 ± 0.82	0.956
Minimum temperature of the affected side	32.13 ± 2.68	31.93 ± 1.35	0.396
Minimum temperature of the contralateral side	32.05 ± 2.31	31.86 ± 1.34	0.396
Average temperature of the affected side	33.82 ± 2.01	33.41 ± 0.84	0.557
Average temperature of the contralateral side	33.90 ± 2.11	33.43 ± 0.82	0.417

**p* < 0.05, data are presented as mean ± standard deviation, *n* = 54. The rank sum test was used.

were men with a median age of 52 years. Because this trial was conducted for the first acupuncture session, there were no dropouts during the study.

As is shown in Fig. 1 set as an example, 2 × 2 square centimeters around the auditory meatus was the highest temperature section of the whole aural region whether it was before or after acupuncture treatment, so this square region was selected for temperature measurement of all individuals' aural regions.

After acupuncture treatment, Table 1 revealed that the temperature differentials of maximum temperature and minimum temperature of both sides decreased significantly (*p* < 0.05), but the maximum, minimum, and average temperature of bilateral aural regions did not have a significant difference (*p* > 0.05). However, when compared with the scores of the VAS before treatment (5.96 ± 1.91), no significant reduction was observed after treatment (5.47 ± 1.87, *p* = 0.181).

4. Discussion

Although previous studies confirmed the efficacy and safety of acupuncture treatment at TE3 and TE5 for tinnitus, we found neither significant relief of tinnitus through the VAS within a 30-minute treatment session nor the changes of maximum and average temperatures of bilateral aural regions which suggested that the alleviation of tinnitus was not significant after one acupuncture session. Nearly all the previous studies had treatment courses ranging from 7 days to 5 weeks or longer and observed the significant relief of tinnitus via the VAS. Many patients with tinnitus have a chronic process, where treatments reduce the frequency or intensity of tinnitus progressively and slowly in most cases [1], indicating that only one acupuncture treatment session might be not enough to receive ideal efficacy. According to the study by Ma [19], both proximal and distal acupoints had significant efficacy for tinnitus, but the effective rate was a bit lower with distal acupoints compared with proximal acupoints, which might be another potential reason. As a matter of fact, on the basis of the acknowledged clinical efficacy of acupuncture for tinnitus already confirmed by two latest meta-analyses [12,20], the leading objective of our pilot study is to take the first step to find out the possible mechanisms of acupuncture in patients with tinnitus and ascertain the underlying etiological factors of tinnitus.

Only one previous study [21] set temperature measurement as one of the efficacy assessment indicators, which

applied acupuncture to trigger points (TrPs) locating on the trapezius and sternocleidomastoid as well as acupoints (both proximal and distal). The captured IRT images of TrPs before and after treatment indicated that the significant temperature changes of TrPs had association with the alleviation of tinnitus. Although the study drew a conclusion that TrPs may block cochlear blood flow to increase severity of tinnitus, the cochlear blood flow condition remained unknown. Hence, our pilot study was conducted to measure temperature changes of aural regions to monitor the cochlear blood flow condition.

In our study, most thermal images of ears showed that the highest temperature section in the whole aural region was 2 × 2 square centimeters around the auditory meatus, which was finally selected for temperature measurement. The main physiological structure behind the square region is the cochlea, which is the sensory organ of hearing, and the blood flow conditions in the cochlea are closely associated with temperature changes of the square regions monitored by IRT [22]. Noticeably, we found that the temperature differentials (maximum minus minimum) of both sides that reduced significantly after acupuncture implied that the overall temperature of both sides fluctuated much less than before and proceeded to stabilization, which showed a more steady velocity and a more even distribution to capillaries of blood flow in the bilateral cochlea, thus reversing the cochlear blood flow dysfunction. As a result, the mechanisms of acupuncture for tinnitus are related to the improvement of bilateral cochlear blood flow dysfunction that was found to be one of the etiological factors of tinnitus. Even if only left, TE3 and TE5 were selected to treat left-sided tinnitus, the bilateral temperature differentials were decreased significantly, suggesting the improvement of cochlear blood flow disorders of both sides, which could be partly explained by the TCM distal end-trunk theory of meridian stimulating acupoints located on any unilateral limb will have bilateral effects on the trunk of the body including the head, face, chest, and abdomen.

When interpreting the findings, some limitations should be noted. First, the maximum and average temperatures of bilateral aural regions after treatment were slightly lower than before in most cases. This does not explain the trigger of high temperatures and infrared radiation tracking along meridians by acupuncture [21,22] found in a previous study. The reason for this might be due to the fact that the IRT images were captured at only two time points (before and after acupuncture treatment), making it difficult to get the

information of continuous temperature fluctuation, or the 10-minute rest for participants to calm down before the first measurement was insufficient for the body temperature to stabilize. Second, the sample size was not large enough for significant results.

Owing to limitations in our study, we have planned another study with a large sample size to set a longer rest time for participants to make sure their body temperatures are stabilized before the first measurement. Then, we will capture IRT images of bilateral aural regions every two minutes to monitor the continuous thermal changes within the whole session. Owing to a lack of a method to quantify cochlear blood flow, we will also use the combination of IRT, the laser Doppler flowmeter, and the hemotachometer to determine the significant associations between changes of cochlear blood flow condition and the effects of acupuncture, aiming at finding out the mechanisms of acupuncture treatment for tinnitus.

5. Conclusion

This pilot study showed that the acupuncture's effects for tinnitus were associated with the improvement of the cochlear blood flow via the IRT test. The bilateral effects made by acupuncture at distal acupoints unilaterally could be partly explained by the TCM distal end-trunk theory of meridian. A well-designed randomized controlled trial will be conducted by us to find out more about the underlying mechanisms of acupuncture for tinnitus.

Disclosure statement

No competing financial interest exists.

Author contribution

W.C. and A.W.C. designed the study. W.C., A.W.C., L.D., and W.D.S. conducted the study. A.W.C. analyzed the data. W.C. drafted the manuscript. All the authors read and approved the final version of the manuscript accepted for publication and agreed to be accountable for all aspects of the work.

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