**Infrared thermography and meridian-effect evidence and explanation in Bell’s palsy patients treated by moxibustion at the Hegu (LI4) acupoint**

**Overall regulation or a specific target?**

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**Abstract**

Subjects with Bell’s palsy and healthy individuals were treated with moxibustion thermal stimulation on the Hegu (LI4) acupoint: an infrared thermal imaging system was used to observe facial-temperature changes. Bell’s palsy patients developed low or high temperatures at the affected side, with poor symmetry. Healthy people showed high temperatures on the forehead, medial angle of the eye, nasal ala and around the lips, but low temperatures on bilateral cheeks, thus forming a “T-type hot area” in the face, with good temperature symmetry. Moxibustion treatment for 11 minutes significantly improved high asymmetry in temperature in the faces of Bell’s palsy patients. This evidence indicates that moxibustion treatment on Hegu enables increases in facial temperatures in healthy people and Bell’s palsy patients, especially around the lips. Moxibustion stimulation at the Hegu not only improves the global circulation but also has specific effects on the lips in Bell’s palsy patients, but the underlying mechanism needs further investigation.

**Key Words:** Bell’s palsy; infrared; skin temperature; face; moxibustion; neural regeneration

**Abbreviations:** BP, Bell’s palsy; MRI, magnetic resonance imaging; IRT, infrared thermography

**INTRODUCTION**

Hegu (LI4) is one of the main points in the acupuncture treatment of Bell’s palsy (BP)¹. Acupuncture at Hegu can improve the amplitude of instant evoked potentials in the damaged facial nerve². The Hegu point intersects with sensory afferent pathways of the face and mouth in the central nervous system³. Gasserian ganglions elicit a projection to Hegu and projections branch to the face⁴. The anatomical basis of Hegu for treating facial disorders. Several functional magnetic resonance imaging (MRI) studies have demonstrated that acupuncture at Hegu can enhance or reduce magnetic resonance imaging signals in the cerebral cortex⁵, limbic system⁶ and several areas in the cerebellum⁷. Electro-acupuncture at Hegu causes the same change of signals (enhanced or reduced) in the brain as that seen with electroacupuncture in the mouth⁸. This finding suggests that acupuncture at Hegu and in the face is due to actions in similar parts of the brain. However, most studies have relied upon small study populations, many confounding factors and appreciable differences between individuals⁹.

Infrared thermography (IRT) is a new technology used to observe altered temperatures in body regions. After acupuncture at Hegu, facial temperature was increased in subjects with facial paralysis; the most rapid area of warming was the mouth, then the nasal ala and mouth corner on the affected side⁹. These changes were also observed in healthy subjects after acupuncture at Hegu¹⁰. Unfortunately, there is little evidence from controlled trials between healthy people and those with BP. Song et al¹¹ found that acupuncture stimulation of Hegu could significantly increase mouth temperature, whereas acupuncture stimulation of Guangming (GB37) significantly increased the temperature at the eyes of healthy and affected sides, which suggested the specificity of the Hegu acupoint. The aforementioned studies verified the impact of acupuncture at Hegu on facial thermography.

We wanted to study the role of moxibustion (a thermal stimulus) at Hegu on the faces of BP patients. Hence, we needed to obtain infrared thermographs of the face in healthy subjects and those with BP. Healthy people have identical facial temperature at the left and right side¹², and the temperature of...
acupoints correspond with blood perfusion. Scholars found that the temperature at the inner canthus, mouth, lips, nasolabial fold and forehead was higher than the average facial temperature in healthy people\textsuperscript{[14]}, and that high temperatures contributed to meridian effects \textsuperscript{[15]}, suggesting that high temperatures occurred along the urinary bladder meridian. Whether a high temperature is caused by the normal physiological processes of the human body or whether it is due to local superficial blood vessels and abundant blood flow or urinary bladder meridian and stomach meridians is not known. IRT results have shown significant differences and poor symmetry in the temperature between two sides of acupoint regions in the faces of individuals with peripheral facial paralysis\textsuperscript{[16]}. Patients were also reported to develop congestive changes at the acute facial paralysis side and ischemic changes at the chronic facial paralysis side\textsuperscript{[17]}, but those data were inconclusive due to a small study population.

We aimed to address three issues. First, we wanted to clearly show that IRT can be done in healthy people and BP patients. Second, we wished to observe the effect of moxibustion at Hegu on the instant thermal effects in the faces of two groups of subjects. Last, we wanted to monitor (in real time) the altered facial temperatures after moxibustion stimulation at Hegu to analyze the time-effect relationship of moxibustion.

**RESULTS**

**Quantitative analyses of involved subjects**

Sixty subjects were involved: 30 healthy people (controls) and 30 BP patients (BP group). They all entered the final analysis. Each group was treated with moxibustion stimulation at Hegu. An infrared thermal imaging camera was used to dynamically observe changes in facial temperature in real time. There were no significant differences in age and sex between the two groups ($P > 0.05$, two-sample $t$-test; Table 1).

**Table 1 General information of subjects**

| Group               | Age (mean±SD, year) | Gender (n) |
|---------------------|---------------------|------------|
| Control             | 42.5±15.5           | 19 Male    | 11 Female |
| Bell’s palsy        | 47.3±10.6           | 14 Male    | 16 Female |

**Performance of facial IRT in healthy subjects and BP patients before and after stimulation with moxibustion**

Before moxibustion treatment, facial IRT showed high temperatures at the forehead, inner canthus, nasal ala, and mouth corner, and low temperatures in both cheeks in the control group. Therefore, a T-shaped “hot area” was formed on the face with balanced temperatures and good symmetry (Figure 1A) with coincided with facial vascular distribution (Figure 1G). In BP patients, bilateral temperature was asymmetric: the temperature at the affected side was higher (Figure 1C) or lower (Figure 1D) than the contralateral side.

![Before moxibustion treatment](image1A)
![After moxibustion treatment](image1B)

![Control group](image1C)
![BP group (high temperature at the affected side)](image1D)

![BP group (low temperature at the affected side)](image1E)
![BP group (normal temperature)](image1F)

![Facial infrared thermography data](image1G)

**Figure 1** Facial infrared thermography data of healthy people (A–B) and Bell’s palsy (BP) patients (C–F) before and after moxibustion treatment.

Before moxibustion treatment, BP patients showed high or low temperatures at the affected side, with an asymmetric bilateral temperature. The control group showed high temperatures at the forehead, inner canthus, nasal ala, and mouth corner, but low temperatures at bilateral cheeks, with good symmetry in bilateral temperature.

After moxibustion treatment, in BP patients with a high temperature at the affected side, the temperature at the unaffected side was increased; in BP patients with a low temperature at the affected side, the temperature in the low-temperature area was increased, with symmetry of bilateral temperatures.

Moxibustion at Hegu (LI4) significantly increased temperatures at the mouth and nose in healthy people. Normal facial blood vessels (G) were distributed along the forehead, inner canthus, nasal ala, and lips.
After moxibustion treatment, the temperature in the mouth and nasal ala was significantly increased in all 30 cases of the control group (Figure 1B). In BP patients with a high temperature at the affected side, the temperature at the unaffected side was increased in 25/30 subjects (Figure 1D) with a symmetry of bilateral temperatures. In BP patients with a low temperature at the affected side, the temperature at the low-temperature area was increased after moxibustion stimulation in 5/30 subjects (Figure 1F) with a symmetry of bilateral temperatures.

Changes in facial temperature before and after moxibustion stimulation at Hegu

The facial temperature was increased in healthy people after moxibustion stimulation at Hegu, especially around the lips (P < 0.05; Table 2). Facial regional temperature in BP patients was increased after moxibustion stimulation at Hegu, and was significantly increased around the lips at the unaffected side (P < 0.05; Table 3).

| Table 2 | Regional correction temperature (°C) change in the control group before and after moxibustion treatment |
|---------|--------------------------------------------------------------------------------------------------|
| Site    | Before moxibustion treatment | After moxibustion treatment | t   |
|---------|------------------------------|-----------------------------|-----|
| Forehead| 5.70±1.06                    | 5.75±1.17                   | 0.358|
| Inner canthus | 6.92±1.11                    | 6.97±1.19                   | 0.435|
| Pars zygomatica | 5.83±1.07                    | 6.10±1.07                   | 1.991|
| Nose    | 6.87±1.16                    | 7.14±1.18                   | 1.973|
| Lips    | 6.21±1.14                    | 6.80±1.22*                  | 5.024|

*P < 0.05, vs. before moxibustion. Data are expressed as mean ± SD, n = 30. The difference from the measured temperature and the background temperature was considered to be the correction temperature.

Temperature changes before and after moxibustion treatment were compared using the paired sample t-test.

| Table 3 | Regional correction temperature (°C) change in Bell’s palsy patients group before and after moxibustion |
|---------|--------------------------------------------------------------------------------------------------|
| Site    | Before moxibustion | After moxibustion | t   |
|---------|-------------------|-------------------|-----|
| Forehead| Unaffected side  | 5.61±1.03         | 5.95±0.93 | 1.431|
|         | Affected side    | 5.78±0.93         | 6.15±1.06 | 1.637|
| Inner canthus | Unaffected side  | 6.95±1.01         | 7.22±1.02 | 1.366|
|         | Affected side    | 6.96±0.88         | 7.26±1.09 | 1.481|
| Pars zygomatica | Unaffected side  | 5.74±1.31         | 6.14±1.10 | 2.069|
|         | Affected side    | 6.07±1.39         | 6.58±1.13 | 1.990|
| Nasal ala | Unaffected side  | 6.80±0.99         | 7.13±1.03 | 1.444|
|         | Affected side    | 7.01±1.04         | 6.88±1.13 | 1.326|
| Lips    | Unaffected side  | 6.37±0.94         | 7.00±0.87* | 2.717|
|         | Affected side    | 6.80±0.91         | 7.12±1.07 | 1.363|

*P < 0.05, vs. before moxibustion treatment. Data are expressed as mean ± SD, n = 30. The difference from the measured temperature and background temperature was considered to be the correction temperature.

Temperature changes before and after moxibustion treatment were compared using the paired sample t-test.

Change in facial temperature before and after moxibustion stimulation at Hegu

There were no significant differences in the facial temperature in healthy people before and after moxibustion stimulation. Temperature differences around the lips and nose became smaller in BP patients after moxibustion stimulation, especially around the lips (P < 0.05; Table 4).

| Table 4 | Facial-temperature (°C) differences before and after moxibustion stimulation at Hegu (LI4) |
|---------|--------------------------------------------------------------------------------------------------|
| Group   | Site                | Before moxibustion treatment | After moxibustion treatment | t   |
|---------|---------------------|-----------------------------|-----------------------------|-----|
| Control | Forehead            | 0.38±0.33                   | 0.31±0.24                   | 0.844|
|         | Inner canthus       | 0.22±0.21                   | 0.21±0.16                   | 0.309|
|         | Pars zygomatica     | 0.39±0.37                   | 0.38±0.27                   | 0.171|
|         | Nasal ala           | 0.31±0.24                   | 0.28±0.19                   | 0.735|
|         | Around lips         | 0.46±0.31                   | 0.34±0.21                   | 1.644|
| Bell’s palsy | Forehead            | 0.28±0.29                   | 0.36±0.24                   | 1.327|
|         | Inner canthus       | 0.23±0.22                   | 0.23±0.16                   | 0.105|
|         | Pars zygomatica     | 0.43±0.36                   | 0.48±0.41                   | 0.558|
|         | Nasal ala           | 0.38±0.50                   | 0.24±0.16                   | 1.029|
|         | Around lips         | 0.43±0.27                   | 0.27±0.14*                  | 2.222|

*P < 0.05, vs. before moxibustion treatment. Data are expressed as mean ± SD, n = 30. The difference from the measured temperature and background temperature was considered to be the correction temperature.

The difference was considered to be the temperature difference before and after moxibustion treatment and was compared using the paired sample t-test.

Analyses of the maximum temperature around the lips after moxibustion stimulation at Hegu

The temperature around the lips in the control group reached a peak 12-20 minutes after moxibustion stimulation (14.27 ± 5.27 minutes), whereas the peak in the BP group occurred 6-16 minutes after moxibustion stimulation (11.40 ± 4.82 minutes). The time to the maximum temperature in the BP group was significantly shorter than that in the control group (two sample t-test, t = 2.199, P < 0.05; Figure 2).

Figure 2 Comparison of the maximum temperature around the lips in the two groups after moxibustion treatment at Hegu (LI4).

The peak in the control group occurred 12-20 minutes after moxibustion treatment whereas that in the Bell’s palsy group occurred 6-16 minutes after moxibustion treatment. Frequency (n) refers to the number of cases reaching a peak at a certain time point.
DISCUSSION

IRT of the faces of healthy people and BP patients
The present study showed high temperatures in the forehead, inner canthus, nasal ala and mouth corner, and a low temperature in both cheeks of healthy people, thereby forming a symmetric T-shaped hot area. Scholars believe that these facial IRT data result from meridian effects travelling along urinary bladder or stomach meridians. We think that this is a physiological phenomenon rather than meridian phenomenon. The head, face, forehead, nasal ala and mouth are facial arterial and venous superficial areas, so they have a high temperature. The bilateral cheeks comprise deep blood vessels, so they have low temperatures. In the present study, BP patients showed asymmetric facial temperatures on two sides, low or high temperature at the affected side. This evidence was determined by the state of local muscle tissue (relaxation or spasm) and local blood circulation. In addition, the infrared thermograph image was completely (not partially) changed after moxibustion stimulation: the facial temperature was increased in an overall and specific fashion. Therefore, we analyzed the temperature difference in different regions (especially between the left and right) in the same frame of image (whereas previous studies adopted anterior and posterior images as an indicator of temperature difference). Our experimental findings not only comprehensively analyzed facial temperature, but also captured specific changes sensitively, thereby reducing errors.

Correlation between the Hegu acupoint and face-meridian evidence
Hegu is an important therapeutic acupoint for facial disorders, but there is little evidence addressing the correlation between Hegu and the face. Acupuncturing Hegu can increase mouth temperature\textsuperscript{[15]}, but the underlying mechanism remains unclear. We showed that moxibustion stimulation at Hegu could increase body temperature at normal physiological hot areas, indicating an improvement in facial circulation. The temperature change around the lips was more specific than in other areas, suggesting that the lips are a specific area affected by Hegu.

Several infrared studies have reported meridian high-temperature lines in humans, which is consistent with classical meridians. For example, Hu \textit{et al}.\textsuperscript{[19]} observed paths of infrared radiation on the surface of the human body under natural conditions. Xu \textit{et al}.\textsuperscript{[20]} found that acupuncture could induce infrared radiation to track along meridians. Zhang \textit{et al}.\textsuperscript{[21]} found that acupuncture, electroacupuncture, moxibustion, fire needles, and catgut implantation at acupoints could trigger high temperatures along meridians. We did not observe an obvious linear correlation between the Hegu point and the lips on IRT images. However, we did observed a relationship between moxibustion stimulation points and distal parts, which we termed “target thermal effects”. We speculate that the acupoints have their potency sites, and that stimulation of acupoints can affect the corresponding site. Attention has been paid to study the functions of meridian lines, and various hypotheses have been put forward to distinguish the “line” from common tissue. It has been suggested to transform the line to a diagram and then describing meridian theory from the meridian-site relationship, local-overall relationship and distal end-trunk relationship to understand the essence of meridian theory.

Moxibustion stimulation at Hegu treats BP: mechanisms underlying overall regulation and specific targets
We showed that moxibustion stimulation at Hegu increased the facial temperature at the original physiological hot area. This finding suggested that this effect was not derived from direct heat conduction. Instead it was by heat stimulation on acupoints regulating the nervous system, which activated sympathetic and parasympathetic regulation of vasodilation, thereby affecting facial blood flow as well as promoting the repair and regeneration of facial nerves and muscles in BP patients. However, moxibustion stimulation also caused an increment in the temperature of lips. This is believed to be a specific effect of acupoints and represented a “stimulus-reaction”. The mechanism of action of this effect needs further study.

We also found that the time to peak facial thermal effects was approximately 15 minutes after moxibustion stimulation in healthy people, and approximately 10 minutes in BP patients. The reason is based upon the duration of the response to receiving stimulation, integrating the central signals and eliciting the reaction. Autonomic nerves are involved in vascular regulation, so their reaction rates are slower than those of sensory and motor nerves. The time to peak facial thermal effects in BP patients was significantly shorter than in healthy subjects. This was because muscle relaxation at the affected side of BP patients resulted in less thermal resistance against cycles in the blood circulation and earlier displayed improvements in such cycles.

SUBJECTS AND METHODS

Design
A non-randomized, concurrent controlled trial.

Subjects
BP group
Thirty BP patients volunteered to participate in trials at the Department of Acupuncture and Moxibustion in Chinese PLA General Hospital (Beijing, China) from March to May in 2011. They were recruited via newspaper advertisements. They aged 24–63 years with disease duration of 2 months. Diagnostic criteria: BP was diagnosed if there was an acute onset and one side of facial muscle paralysis\textsuperscript{[22]}. 
Facial muscle paralysis caused by cancer, shingles and meningitis was excluded.
Inclusion criteria: (1) age 16-70 years; (2) disease onset < 3 months; (3) patients not receiving facial thermal imaging treatment such as acupuncture, cupping, fomentation or massage within the previous week.
Exclusion criteria: patients with: (1) recent herpes-virus infection or signs of herpes virus infection of the auricle or external auditory canal; (2) secondary peripheral facial paralysis such as Guillain-Barré syndrome, mumps or intracranial lesions; (3) severe primary disease affecting the cardiovascular, cerebrovascular or hematopoietic systems or the liver, kidneys, or lungs; (4) mental illness; (5) diabetes mellitus; (6) poor facial IRT data due to other dysfunctions such as colds, rhinitis, conjunctivitis, insomnia or cerebral insufficiency.

Control group
Thirty healthy volunteers aged 24–55 years were recruited via newspaper advertisement from March to May in 2011.
Inclusion criteria: (1) general physical examinations were normal with respect to ophthalmology, otolaryngology, dentistry and orthopedics; (2) routine imaging (chest radiograph, ultrasonography) and laboratory examinations (blood chemistry, blood microbial examination) were normal; (3) patients had no significant malaise within the previous week; (4) patients not receiving facial thermal imaging treatment such as acupuncture, cupping, sticking, or massage within the last 1 week.
Exclusion criteria: Subjects with poor facial thermography data due to dysfunctions such as colds, rhinitis, conjunctivitis, insomnia or cerebral insufficiency according to IRT were excluded.
According to the Administrative Regulations of Medical Institutions issued by the State Council of China[23], all patients and their relatives were informed of the experimental program and potential risks before study commencement. All subjects provided written informed consent.

Methods
Moxibustion
Subjects sat with their forearm placed naturally on a table. A smoke-free moxibustion strip (Nanyang Lively Moxa Grass Biologicals Co., Ltd., Nanyang, China) was ignited and inserted into a moxibustion frame (Shoumin Moxibustion Tool Factory, Tianchang City, Anhui Province, China), equal to bilateral Hegu (located between the first and second metacarpal bone, at the midpoint of second metacarpal radial side) for suspended moxibustion (far away from the skin). Subjects can adjust the distance to feel local warmth without burning their skin. Moxibustion ash was removed every 10 minutes, and the total treatment lasted 20 minutes. The operational procedures were identical for the two groups.

Image acquisition
Images were acquired in a shielded room with no air convection, no direct sunlight or abnormal radiation source maintained at 24–26°C and 60% humidity. Subjects were exposed to certain sites for 15 minutes until breathing and heart rate stabilized with no sweating. Anteroposterior IRT images were acquired with an infrared thermal imaging camera (Guangzhou SAT Power Infrared Technology Co., Ltd., Guangzhou City, China). This camera was a CK350 non-cooled focal plane medical infrared imaging device with an image resolution of 384 × 288, temperature resolution of 0.08°C, spatial resolution ≤ 1.5 mrad, and data collection of 30 frames/s. One image was acquired before moxibustion stimulation, every 2 minutes during moxibustion treatment, and after moxibustion withdrawal.

Analyses of IRT images
Collected images were analyzed with a TMTSys analysis system (Beijing Aierci Infrared Medical Science and Technology Limited Company, Beijing, China). Image files were stored on a personal computer and analyzed after the end of the experiment.

Statistical analyses
Measurement data are mean ± SD and were analyzed with SPSS 14.0 statistical software (SPSS, Chicago, IL, USA). Data that were normally distributed were compared using the paired sample t-test, whereas other data (e.g., time to peak facial thermal effects) were compared using the two-sample t-test. P < 0.05 was considered significant.

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Conflicts of interest: None declared.
Ethical approval: The study protocol was approved by the Ethics Committee of Chinese PLA General Hospital in China.
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