Infrared thermoimages display of body surface temperature reaction in experimental cholecystitis

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AIM: To display the thermoimages of the body surface in experimental cholecystitis, to observe the body surface temperature reaction in visceral disorders, and to study if the theory of body surface-viscera correlation is true and the mechanism of temperature changes along the meridians.

METHODS: By injecting bacteria suspension into the stricture bile duct and gallbladder, 21 rabbits were prepared as acute pyogenic choangiocholecystitis models, with another 8 rabbits prepared by the same process except without injection of bacteria suspension as control. The body surface infrared thermoimages were continuously observed on the hair shaven rabbit skin with AGA-782 thermovision 24h before, 1-11d after and (2,3wk) 4wk after the operation with a total of over 10 records of thermoimages.

RESULTS: Twelve cases out of 21 rabbits with cholecystitis revealed bi-lateral longitudinal high temperature lines in its trunk; with negative findings in the control group. The high-temperature line appeared on d1-d2, first in the right trunk, after the preparation of the model, about 7d after the model preparation, the lines appeared at the left side too, persisting for 4wk. The hyper-temperature line revealed 1.1-2.7°C higher than before the model preparation, 0.7-2.5°C higher than the surrounding skin. The length of the high temperature line might reach a half length of the body trunk, or as long as the whole body itself.

CONCLUSION: The appearance of the longitudinal high temperature lines at the lateral aspects of the trunk in the experimental group is directly bound up with the experimental animals pyogenic cholecystitis, with its running course quite similar to that of the Gallbladder Channel of Foot Shaoyang, but different to the zones of hyperalgiesia and site of referred pain in cholecystitis.

Zhang D,Zhu YG,Wang SY,Ma HM, Ye YY,Fu WX,Hu WG. Infrared thermoimages display of body surface temperature reaction in experimental cholecystitis. World J Gastroenterol 2002;8(2):323-327

INTRODUCTION

The reactions on body surface due to visceral lesion have long aroused the interest of investigators. As early as 1889, the Head’s zone was observed and the referred pain was interpreted by the two concepts of pre-spinal and intra-spinal viscero-somatic association neurons several decades later. The above-mentioned zones of hyperalgiesia were mainly based on the complaint of the patients themselves, and the accompanying reaction of nerve-blood vessel-muscle-sclerotic zone-dermatomere is again a kind of pathological changes with indefinite boundary, still short of objective examination. Formerly, some scholars have explored the relation between the visceral lesion and temperature of the body surface, which was limited only to the region around the lesion, like observation, for instance, around cholecystitis. The theory of meridian in Traditional Chinese Medicine(TCM) indicates that, the meridians connect the viscera internally and the body surface externally. Physiologically, it serves for the flowing of blood-qi, and pathologically, reflects disease changes. Acupuncture is a therapy of entrails by stimulating acupoints along channels on the body surface[1-6]. However, exactly how the temperature changes induced by visceral disorders, whether it occurs at the meridians and acupoints through TCM theory or appears at the special regions of Head’s zone or referred pain on the basis of Western medicine, or even only appears around the lesions, is still a question attracting investigators’ interests. Infrared thermography, a modern measuring temperature method, could be used for diagnosing some diseases and medical basic researches, such as the displaying of temperature imaging of cerebral cortex[7,8], effect of acupuncture on brain[9,10] and study of medicine, or even only appears around the lesions, is still a question attracting investigators’ interests. Infrared thermography, a modern measuring temperature method, could be used for diagnosing some diseases and medical basic researches, such as the displaying of temperature imaging of cerebral cortex[7,8], effect of acupuncture on brain[9,10] and study of principle of acupuncture[11,12], etc. Based on past work[7-10], we have studied this topic by the above-mentioned animal models for continuous follow-up examinations so as to investigate whether cholecystitis can lead to body surface temperature reactions and their locations in this paper.

MATERIALS AND METHODS

Experimental animal

Adult healthy rabbits, 21 in the experimental group, and 8 in the control group in both sexes, weighing 3.0±0.35kg, supplied by Department of Experimental Animals from our Academy.

Animal model

The models were made based on the method reported by Xu et al[11]. The animals were anesthetized with sodium phenobarbital through auricular marginal vessel (45mg·kg⁻¹) with abdominal hairs shaved. After routine anesthesia, an incision was made at the mid-abdominal line from the xyphoid process to the umbilicus and the abdomen was opened. We isolated a small segment of the common bile duct 1cm from the duodenum, inserted a hard plastic tube 0.5cm long opened longitudinally with a caliber just a little more slender than the common bile duct, and then put outside the bile duct. The lower end of the tube was penetrated with a thread and ligated to close its open end. Thus, the duct was strictured in an incomplete blocked manner. 1ml suspension prepared by mixing a piece of rabbit dung with 10mL was injected with saline into the gallbladder to create a pyogenic cholecystitis. We sutured the wound and applied some antibiotics locally and continued to feed the animal. After the animals resumed its consciousness, there were manifestations including loss of appetite, icteric jaundice in the sclera, auricles, and skin to different degrees, with deep-colored urine. By anatomy, when the experiment was over, the gallbladder could be seen enlarged, dilated, with thickened wall and fibrosis, indicating a chronic inflammation. By the same process, the common bile ducts of the animals in the control group were isolated but with no bacterial suspension administered. After we sutured the wounds the feeding was continued.

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Observation process
Before every thermoinage was taken and the model operations were performed in the two groups, the hairs at the back and both sides of the trunk were cut. The infrared thermoinages were taken 24h before the operation and 1-11d, and (2, 3wk) 4wk after the operations at the hairless areas to investigate the temperature changes and its evolution before and after the models were formed.

Experimental instrument and surroundings
Swedish AGA-782 Infrared thermovision was applied for observation of thermoinages with the thermosensitivity being 0.1 (0.025°C available after computerized processing). The images of temperature distribution of the observed parts were taken with the infrared camera of the instrument, and continuous images were taken by the black-white demonstrator and color monitor. The infrared thermoinage was processed, reserved and analyzed by equipment system TC-800 computer and DISCO3.1 thermoinage program, while the absolute values of temperature were checked by the DH-1 Model Thermal Calibration Source (Figure 1). The room temperatures were 25.5-29.6°C, and relative humidities 33-60%.

Method for observation and recording of thermoinages of body surface
The camera of the thermovision was placed 1 meter above the observed parts, while the Thermal Calibration Source within the visual field of the camera so as to indicate the absolute temperature. The thermoinages were recorded at the hairless areas (for fixation of the animal, Figure 2), more than 10 follow-up continuous observations were made 1d before and 4 wk after the operation.

RESULTS
Symptoms of the animal models
The operation process went smoothly, with the animals resuming its consciousness 4-5h after the operation. All conditions but food taking remained normal, without any inflammatory reactions in the wound. In three cases, the sclera and auricle became icteric 1d after operation, another 16 cases showed such jaundice 2-5d after operation. Generally, general jaundice of the skin appeared 3-5d after operation. All 21 animals had deep-colored urine and fever to certain degree. One week later, the animal returned to normal temperature without jaundice, but the appetite was still abnormal, with emaciation, indicating chronic inflammation. In our series, 5 cases died 7d later, 1 died 9d later, and another 1 died 18d later. The remaining animals survived, and 12 revealed longitudinal high temperature lines along the lateral aspects of the trunk, which was similar to the running course of Gallbladder Channel of Foot Shaoyang. The lines elongated as time went on (Figure 3).

Figure 3 Continuous display of the infrared thermoinages of rabbit trunk with cholecystitis in 2 rabbits.

I. The distribution and evolution of high temperature line on the infrared thermoinage of No.11 rabbit’s trunk (back and axillary aspect) A: before cholecystitis model; B:1d after cholecystitis, high temperature line appeared in the lateral aspect; C: on d2; D: on d3; E: on d4; F: on d7, high temperature line began to appear at the left side; G: on d8; H: on d9, marked bilateral high temperature lines; I: on d10; J: on d11, K: on d30, high temperature line remained.

II. The distribution and evolution of high temperature line on the infrared thermoinage of No.8 rabbit’s trunk (back and axillary aspect) A: before
cholecystitis model; B: 1d after cholecystitis; C: on d2, right high temperature line; D: on d3, marked right high temperature line appeared; E: on d4; F: on d7, left high temperature line appeared; G: on d8; H: on d9, marked bilateral high temperature lines; I: on d10; J: on d11; K: on d30, bilateral high temperature lines disappeared.

The distribution is shown by the dotted line in Figure 1. The other 9 rabbits didn’t show such lines. Only some spotted high temperature areas could be seen. There might even be lower temperature of the body surface.

**Features of high temperature lines in the trunk in acute cholecystitis**

The features included: (1) 9 out of the 12 animals with longitudinal high temperature line in the trunk were bilateral, and the other 3 unilateral; (2) Most of the high temperature lines first appeared in the right side, among them, 3 cases appeared 1d after operation; 5 cases after d2. The lines in the left side appeared rather late. All left high temperature lines appeared 7d after operation except 1 case appeared only 2d after; (3) The lines were thread (band) shaped, first rather short and elongated as time elapsed, the longest being as long as the trunk itself; (4) The duration of the existing lines lasted, with over 30d as the longest; (5) The temperature of the lines was about 0.7-2.5°C higher than that of the surrounding region, about 1.1-2.7°C higher than that before the lesion appeared in the same region.

**The thermoimages of body surface and symptoms of the control animals after operation**

All 8 cases resumed consciousness 4-5h after the operation, with normal activities, without swelling or infection in the wound, without icteric sclera, auricles or deep-colored urine. Body temperatures rose in different degree, with normal appetite and better survival condition. No longitudinal high temperature lines appeared in the trunk 1mo after the operation except that 1 case had some high temperature areas that appeared remittently (Figure 4).

**DISCUSSION**

Reaction on the body surface due to visceral disorders, a phenomenon recognized in both traditional Chinese medicine and western medicine, is called “correlation of body surface and viscera” in modern medicine and “correlation of meridian and viscera” in TCM theory. Though not exactly identical in the description of both systems, yet, they bear the common idea that viscera lesions might be reflected on the body surface. As the largest organ of the body, skin receives all stimulations from outside, preserves body fluid and maintains body heat balance, with a comprehensive function of sensation, secretion, excretion, temperature regulation, and metabolism. There is a close relationship between the body surface and internal viscera. The former always reflects the disorders of the latter. Visible changes can be seen on the skin in diseases such as scleroderma, lupus erythematosus, and iatrogenic dermatitis, therefore, visceral diseases can sometimes be diagnosed by changes in the skin, and conversely, abnormal cutaneous sensation also reflects visceral ailments. The left shoulder pain, for instance, can be seen in myocardial ischemia; interscapular pain, in stomach and pancreas diseases; referred pain in the right shoulder, and scapular pain in liver and gallbladder disorders (Figure 5A), as well as the Head’s zone with clear distribution (pain hypersensitivity) (Figure 5B), and so on.

**Figure 4** The distribution and evolution on infrared thermoimage of control rabbit’s trunk (back and axillary aspect) A: before operation; B: 1d after operation; C: 2d; D: on d3; E: on d4; F: on d7; G: on d8; H: on d9; I: on d10; J: on d11; K: on d22; L: on d30. It can be seen here that there was no longitudinal high temperature line 1 month after the operation.

**Figure 5** Diagram showing referred pain in cholecystitis, Head’s zone and “cutaneous portion” of gallbladder channel. A: Referred pain in cholecystitis; B: Head’s zone; C: “Cutaneous portion” of gallbladder channel on the lateral aspect of the body.
For the Head’s zone, it is interpreted that the nerve impulse comes from the stimulus in the internal organ which, through the posterior root of the spinal cord, arrives at a specific spinal segment and forms an excitation focus in the cord and then reaches the efferent nerve fibers of the same segment via the intermediary association neurons, resulting in the sensory hypersensitivity of the correlative body surface part. This is a visceral-sensory reflection related to a kind of pain sensitive phenomenon that appeared on a certain part of the body surface due to disorders of the internal organs whereas referred pain may be due to the fact that the afferent nerve of the body surface and affected organ share the same spinal posterior nerve root entering the spinal cord, whose never endings project to the same viscero-somatic association neuron. Abundant clinical facts and basic research reveal that there are minute description and summary for the specificities and law of distribution of Head’s zone and referred pain. Though the mechanism of body surface reaction for visceral disorders is still unclear, yet, it is of clinical significance to judge the disorders of the organs by these reaction areas on the body surface. However, the subjective complaints of sensation are not to be used as objective basis for diagnosis. This is why someone observed the relations between the temperature and pain sensation, attempting to apply temperature in the place of subjective complaints. Unfortunately, the correlative relations are still indefinite. Objective phenomena and records for the external manifestations of disorders of internal organ are still rare. The goal of our study is to record the longitudinal zone of high temperature on the lateral trunk by infrared thermography. We noticed that there are significant differences between the recorded longitudinal and the distribution of the 2 pain hypersensitive areas on the body surface.

The past studies show that there are high temperature lines running longitudinally on the human surface whose course is related to the meridians, hence, the title “high temperature lines along meridian” (HTLM). The study of these phenomena with infrared thermography is a great advance on the basis of biophysical studies on acupoints. Acupuncture-moxibustion can raise the skin temperature[15,16]. Although observation on HTLM reveals that the rate of their appearance is rather low under natural condition, it can be raised by acupuncture-moxibustion[17,18]. Although HTLM might need certain inducing factors, such as acu-moxibustion stimuli, there have been a lot of reports; but there are no reports concerning inside stimuli (such as visceral disorders) so far. In the theory of traditional Chinese medicine, it is the meridian system that connects the interior with the exterior, provides the passage for the flowing of blood and Qi, communicates the supercicies with the interior, and regulates Yin and Yang. All internal viscerae connect them through corresponding meridian and collaterals. Once a viscera is ill, it can be manifested on the body surface through their corresponding meridian. The above description in traditional Chinese medicine is rather identical with the observation and study of Head’s zone and referred pain in modern medicine. In the modern studies of meridian phenomena, the dematosis, capillary dilatation in the skin, cutaneous and subcutaneous nodules, depressions, elevation, tenderness, acupoints electric measurement and acupoints temperature examination, etc. along the meridian were all focused on the search for the correlation between the viscera and its corresponding meridian, so as to prove the scientific theory of meridian. Unfortunately, the conclusion is still unclear. Compared with the above theories between traditional Chinese medicine and western medicine, there are both similarities and dissimilarities. The idea that body surface can reflect the diseases of the viscera is the same between the two medical systems, while their locations reflecting the affected viscera are different. Head’s zone is distributed on the basis of neural segments, viz. being transversely distributed in the trunk, while referred pain is distributed in regions or in patches; whereas meridians are distributed longitudinally and in bands. The satisfactory results of Chinese herbal medicine[19,20] and acupuncture-moxibustion[21,22] on digestive diseases demonstrate that it is feasible to apply traditional Chinese medical therapies for diseases in western medicine, acupuncture plays also an impotent role on the research of pathogeny and treatment[23,24], and the difference in the theories of the two medical systems can be unified and verified with objective indices. The acute pyogenic cholecystitis falls under the category of gallbladder disorders in traditional Chinese medicine. In the thermoimage of body surface recorded by infra-red thermography, we observed, for the first time, the longitudinal distribution of high temperature lines on the body trunk, which is different to the zones of hyperalgesia and referred pain area on the body surface in gallbladder disease, but similar to the distribution of “cutaneous portion” of Gallbladder Channel of Foot Shaoyang (Figure 5C), indicating that there is a tendency of temperature reaction on the body surface along the meridian in visceral diseases.

gallbladder diseases could be diagnosed by modern instrument[25]. The rise of body temperature is an index of infection[26,27]. Due to the inflammatory reaction in experimental pyogenic cholecystitis, body temperature is raised, which is a systematic phenomenon. However, in our experiment, the temperature of the longitudinal high temperature lines on the lateral trunk was higher than the surrounding skin, indicating that the existence of the lines was not due to the rise of temperature, or rather, a specific mechanism. Physiologically, high body temperature indicates the degree of energy metabolism and the flowing blood volume in the local part[28,29]. In addition to the interpretation that the distribution of high temperature lines on body surface in cholecystitis can be made by the running course of Gallbladder channel and theory of traditional Chinese medicine, it can also be preliminarily interpreted by blood circulation, metabolism and nervous function. After the gallbladder is affected, the nervous reflex on the body surface reactive area is increased, leading to the increase of metabolism of the skin tissue and blood circulation to meet the needs of recovery of the viscera, hence, the high temperature lines. Formerly, we observed many phenomena of high temperature lines along the meridians, their depths[30,31] and the relationship between autonomic nervous system and the lines[32]. We now further understand, through our present experiment, the mechanism of its appearance, viz. visceral disease being one of the factors responsible for the appearance of the high temperature lines, and the lines along the meridians being a kind of manifestation reflecting visceral pathology. Here, we offer a pictorial basis for the objective verification of meridian-visceral correlation in traditional Chinese medicine, and a supplement to the theory of zones of hyperalgesia and referred pain in modern medicine.

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