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AN EXPERIMENTAL EVALUATION OF AURICULAR DIAGNOSIS: THE SOMATOTOPIC MAPPING OF MUSCULOSKELETAL PAIN AT EAR ACUPUNCTURE POINTS

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SUMMARY

The present study was designed to experimentally evaluate the claims by French and Chinese acupuncturists that a somatotopic mapping of the body is represented upon the external ear. According to this system of diagnosis, areas of the auricle where there is increased electrical conductivity and heightened tenderness to touch correspond to specific areas of the body where there is some pathological condition. The hypothetical map of different bodily regions appears on the external ear as an inverted fetus, with the head represented towards the lower lobule, the hands and feet represented at the uppermost portion of the auricle, and the body in between.

Forty patients were medically examined to determine areas of their body where there was musculoskeletal pain. Each patient was then draped with a sheet to conceal any visible physical problems. The physician conducting the auricular diagnosis had no prior knowledge of the patient's medical condition, but simply examined the patient's ear for areas of elevated skin conductivity or tenderness. The concordance between the established medical diagnosis and the auricular diagnoses was 75.2%. Both quantified readings of electrical current flow and subjective ratings of dermal tenderness were statistically significant in arriving at accurate diagnoses. These results thus support the hypothesis that there is a somatotopic organization of the body represented upon the human auricle.

INTRODUCTION

A large number of studies have now demonstrated the clinical effectiveness of acupuncture for the relief of acute [1,6] and chronic pain [7,11—13, 24,27]. Nonetheless, Western medicine has retained a skeptical attitude toward this oriental treatment modality. The positive clinical findings resulting from acupuncture have been criticized as being primarily due to placebo

effects [22,25,29], hypnotic suggestibility [17,29], or counter-irritation [11,12,24]. Although several authors [4,9,18,37] have presented alternative arguments to counter these criticisms, acupuncture remains a controversial treatment procedure.

Probably the most intriguing aspect of acupuncture has been the utilization of specific meridian points which are located on bodily areas at some distance from the site of pathology. While the regional relief of pain produced by acupuncture can be explained by processes associated with transcutaneous nerve stimulation [6,10] or trigger point injections [12,38], such mechanisms cannot as easily account for the results from treating distant points. Of all the remote acupuncture sites used to alleviate chronic pain, one of the most controversial areas is the acupuncture microsystem located upon the external ear. According to the principles of ear acupuncture, or auriculotherapy, each area of the ear corresponds to a different anatomical portion of the body [31]. These somatotopic points are reportedly consistent from one individual to the next [40].

Although meridian points on the ear were reported in Chinese medical texts over 2000 years ago [39], it was the pioneering work of the French neurologist, Paul Nogier [32], that led to the development of contemporary ear acupuncture charts. Nogier noticed that several of his patients had a particular scar on their ear related to a previous treatment for sciatic pain by lay practitioners. Following a series of his own clinical studies, in which he cauterized, needled, or electrically stimulated different areas of the auricle, Nogier discovered that the treatment of specific sites on the pinna of the ear alleviated clinical problems originating from specific regions of the body. On the basis of this research, Nogier proposed that an orderly, somatotopic relationship existed between different anatomical areas of the body and specific representative points on the ear. The arrangement corresponded to an inverted fetus, with the head represented toward the lower lobule of the ear, the hands and feet represented towards the upper rim of the ear, and the body in between. This work was subsequently transmitted to Chinese acupuncturists who conducted their own studies of ear acupuncture on over 2000 patients and essentially verified the findings of Nogier [15].

Besides assessing the treatment effects resulting from auriculotherapy, both French and Chinese physicians have reported that it is possible to diagnose a variety of pathological conditions by examining the ear [15,32, 40]. When there is a pain problem involving a given area of the body, the corresponding auricular point is said to be "reactive", manifesting greatly increased tenderness and electrical conductivity as compared to surrounding areas of the ear. It is also purported that in some cases, there are also morphological changes or discolorations at these auricular loci.

Several investigators have provided clinical evidence supporting the therapeutic efficacy of auriculotherapy for the relief of pain [8,16,21,23,36], but there has been little controlled research concerning the scientific validity of auricular diagnosis. Unlike treatment outcome studies, which are subject to criticisms of placebo effects and hypnotic suggestibility, diag-

nostic determination studies are not as influenced by such patient response variables. The purpose of the present study was thus to conduct a controlled, double-blind evaluation of auricular diagnosis.

METHODS

Subjects

Forty patient volunteers, 20 males and 20 females, were selected from the Orthopedic Clinic, the Pain Management Clinic, and the Student Health Service of the UCLA Hospitals and Clinics. Their ages ranged from 18 to 66 years, with a mean of 34 years. All subjects provided statements of informed consent and completed a brief report concerning their medical history.

Materials and equipment

A standardized self-report inventory was filled out by all subjects which indicated whether or not they experienced strong or persistent pain in particular areas of their body. For the purposes of this study, 12 areas of the body were considered: hand and fingers, wrist, lower arm and elbow, upper arm and shoulder, neck, head, upper back, lower back, hip and buttocks, upper leg and knee, lower leg and ankle, foot and toes.

Based upon the results of pilot studies indicating that auricular diagnosis was as sensitive to a patient's medical history as to current pain problems, both recent and past pain problems were evaluated on this questionnaire. Pathological conditions which were not presently painful, such as a frac-

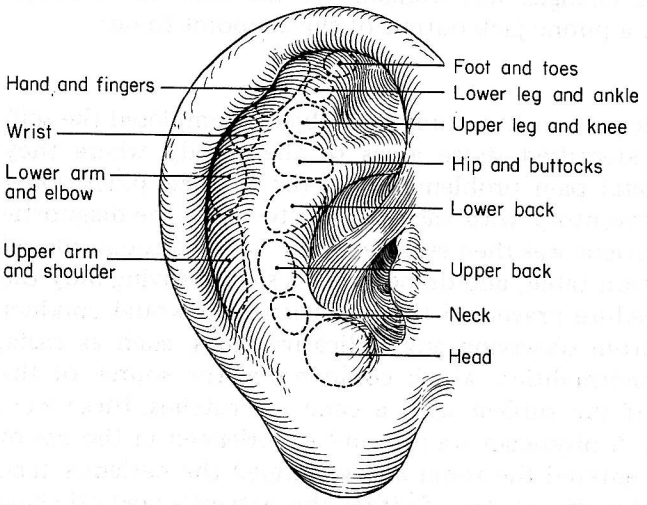

Fig. 1. Somatotopic representation of 12 different regions of the body on specific areas of the external ear. Designation of a localized point within each area of the auricle was based upon the highest electrical conductivity and dermal tenderness values obtained by scanning each area with a metal probe.

tured limb immobilized in a cast, were also indicated. Another form, listing the same 12 areas of the body, was filled out by the physician conducting the auricular diagnosis. This latter form contained information relevant to dermal tenderness, electrical conductivity, and morphological characteristics of the 12 areas of the ear shown in Fig. 1. The exact loci of the auricular points tested were based upon the ear acupuncture maps of Huang [15] and Wexu [40], and upon the clinical experience of the physician doing the examination (R.J.K.).

Auricular diagnosis was determined through the use of a metal probe applied to the patient's ear and an Oriental acupoint finder (The People's Republic of China, Therapy Apparatus). Similar to a galvanic skin resistance (GSR) biofeedback instrument, the acupoint finder utilizes a wheatstone bridge to measure changes in current level. A constant 9 V DC was delivered between two output terminals from this instrument. One output was connected to the ear probe and the other to a metal bar held in the patient's hand, thus forming a complete electrical circuit [15]. A digital current meter (Valhalla Scientific Instruments, Model 4440) was connected in series with this circuit in order to precisely quantify the amount of current flowing through each ear point. Maximal current readings of 300 μA corresponded to areas of lowered skin resistance or increased skin conductance. Since slight variations in applied pressure can alter the measured level of electrical current, a 1.5 mm metal tip probe was specially constructed with a spring-loaded stylus. This probe provided constant pressure for assessing electrical conductivity at the skin surface. Dermal tenderness, however, was assessed with a fixed metal probe in order to accentuate the selective sensitivity of each ear point to applied pressure. Auditory feedback of conductance changes was available to the examiner through an earphone connected to a phone jack output of the acupoint finder.

Procedure

After agreeing to participate in this study, all subjects completed the self-report inventory which identified those areas of their body where they experienced musculoskeletal pain problems. A doctor or nurse practitioner reviewed the self-report inventory with each patient to verify the diagnostic conditions listed. Each patient was then escorted to an isolated room, placed supine upon an examination table, and draped with a sheet, leaving only the head exposed. This procedure prevented the physician who would conduct the auricular diagnosis from observing any indicative clues, such as casts, bandages, or postural abnormalities, which could reveal the source of the patient's pain problem. If the subject used a cane or crutches, these were removed from the room. A physician trained and experienced in the use of auricular diagnosis then entered the room and examined the patient's ears. This physician had no prior knowledge of either the patient's medical chart or the self-report inventory, and was not permitted to ask the patient any questions except those related to the tenderness of different points on the pinna.

After the patient's ears were examined for areas of discoloration, pigmentation, or morphological abnormalities, the auricular surface was cleaned with alcohol. All 12 auricular points on the left and right ears of each subject were examined twice. In the first series, the constant pressure probe was applied to each point and the electrical current reading was recorded. The fixed stylus probe was then used to reexamine each point for perceived dermal tenderness. As each area was touched, the patient was asked to subjectively evaluate the sensitivity of that point using a scale ranging from "0" (no tenderness) to "4" (very tender). None of the patients was aware of the somatotopic map of the ear and a code was used so that the patient did not know which area of the body corresponded to the area of the ear being tested. Since the patient was blind to the somatotopic arrangement on the ear and the physician was blind to the patient's medical condition, the experimental design was in effect double-blind.

After completing his examination, the physician performing the auricular diagnosis categorized the different ear points as either "reactive" (those auricular loci which resulted in heightened tenderness when touched and were associated with high levels of electrical conductivity) or "non-reactive" (those points which were neither tender nor electrically active). Based upon our findings with pilot subjects, the criterion cut-off level for identifying a current reading as "reactive" was set at 50 μA or greater. Evaluation of perceived tenderness depended upon the dermal sensitivity of that subject to any applied pressure. Some subjects tended to give generally high ratings of tenderness while other subjects tended to give generally low tenderness ratings for all auricular loci tested. The physician's designation of each auricular point as being either "reactive" or "non-reactive" was compared to the presence or absence of pain in the corresponding area of the body. Since 12 comparisons were examined in 40 subjects, a total of 480 individual evaluations were obtained for statistical analysis.

RESULTS

Although it was intended that only subjects with localized pain problems be selected for this study (in order to correlate isolated areas of body pathology with specific areas of auricular "reactivity"), most of the patients who were chosen had multiple pain problems. Sometimes the pain problems involved several areas of the same limb, whereas in other cases the problems for a given individual could be as divergent as headaches and a burning sensation in the feet. The use of crutches for a broken leg often created hypersensitivity in the shoulder and arm area. Moreover, pilot work indicated that minor annoyance with an old head concussion or periodic back pain was as detectable with auricular diagnosis as was a recent torn ligament or leg fracture. Shown in Table I are the total number of reported pain problems summed across all 40 subjects for each of the 12 areas of the body which were examined. Although there was not an equal representation from each bodily area under consideration, the presence of pain problems tended to be

TABLE I

NUMBER OF PAIN PROBLEMS PRESENT AT DIFFERENT AREAS OF THE BODY ACROSS ALL SUBJECTS EXAMINED

Bodily area	Number	Bodily area	Number
Hand and fingers	22	Upper back	17
Wrist	19	Lower back	24
Lower arm and elbow	16	Hip and buttocks	22
Upper arm and shoulder	22	Upper leg and knee	22
Neck	25	Lower leg and ankle	21
Head	27	Foot and toes	15

uniform across the different areas of the body which were examined.

As indicated in Table II, most ear points which were designated as "reactive" corresponded to bodily areas where the subject reported that musculoskeletal pain was present, while most "non-reactive" ear points corresponded to areas of the body at which the patient experienced no discomfort. The distribution of "reactive" and "non-reactive" ear points across "pain problem present" and "pain problem absent" bodily regions was highly significant by the χ^2 test ($P < 0.01$) [14]. Combining the number of "reactive" "problem present" ear points (N = 185) with the number of "non-reactive" "problem absent" ear points (N = 176) yielded an overall correct identification rate of 361 out of 480 comparisons, or 75.2%. Incorrect identifications were approximately equally divided between 12.9% false positive points, that is, "reactive" ear points which did not correspond to areas of musculoskeletal pain, and 11.9% false negative points, auricular sites which were labeled "non-reactive" but did represent an area of the body at which musculoskeletal pain was present. For 37 of the 40 subjects, there were more correct identifications than incorrect identifications, which is significant by the Sign test ($P < 0.01$) [13]. The remaining 3 subjects exhibited an equal number of correct and incorrect identifications.

Both the quantified readings obtained from the digital current meter and

TABLE II

CONCURRENCE OF AURICULAR DIAGNOSIS WITH MEDICAL DIAGNOSIS OF MUSCULOSKELETAL PAIN PRESENT AT SPECIFIC BODILY AREAS

N = 480 (12 bodily areas in 40 subjects); $\chi^2 = 120$, df = 1, $P < 0.01$; total correct detections = 75.2%.

Auricular diagnosis	Established medical diagnosis	
	Problem present	Problem absent
Reactive ear points	38.5% (n = 185)	12.9% (n = 62)
Non-reactive ear points	11.9% (n = 57)	36.7% (n = 176)

TABLE III

MEAN ELECTRICAL CONDUCTIVITY AND DERMAL TENDERNESS AT EAR POINTS RELATED TO SPECIFIC BODILY AREAS WHERE PAIN PROBLEMS WERE PRESENT OR ABSENT

N = 960 right and left ear points.

		Established medical diagnosis	
		Problem present	Problem absent
Mean auricular conductivity (0—300 μA)	$\bar{X}$	60.3	38.6
	S.D.	± 42.6 [a]	± 33.1
Mean auricular tenderness (0—4 scale)	$\bar{X}$	1.8	1.2
	S.D.	± 1.3 [b]	± 1.5

[a] Conductivity: $t = 8.81$, df = 959, $P < 0.01$.
[b] Tenderness: $t = 6.47$, df = 959, $P < 0.01$.

the subjective patient reports of dermal tenderness contributed to the accuracy of the auricular diagnosis findings. Depicted in Table III are the mean electrical conductivity and mean dermal tenderness values averaged across the 12 right and left ear points for all 40 subjects. At those auricular loci which corresponded to an area of the body where some pain problem was present, the mean electrical current readings were 60.3 μA, which was significantly higher than the mean value of 38.6 μA obtained at ear points which were not associated with body pathology ($P < 0.01$, t test) [14]. Although the mean differences were not as large, the mean auricular tenderness at pain problem present sites, 1.8 on a "0" to "4" scale, was still significantly greater than the mean tenderness value of 1.2 found at ear points corresponding to problem-free bodily regions ($P < 0.01$, t test).

The criteria used to distinguish "reactive" and "non-reactive" ear points were remarkably consistent across all subjects examined. The conductivity criterion value of 50 μA was surpassed by 90.6% of all "reactive" sites whereas only 16.3% of all "non-reactive" ear points were 50 μA or greater. Although there was not a large difference in mean tenderness ratings, 74.2% of all ear points designated as "reactive" by the auricular diagnosis physician were rated by the patients as "2" or more on dermal tenderness. Only 47.8% of the auricular points categorized as "non-reactive" were given dermal tenderness ratings of "2" or higher.

Because of the more quantified nature of the electrical current readings, when there was a discrepancy between evaluations based upon conductivity level and those based upon tenderness ratings, designation of a point as "reactive" or not was usually decided by high current values. However, a combination of both heightened dermal tenderness and increased electrical conductance served as the most reliable indication that the corresponding bodily area was pathological. In several cases where the electrical current reading was near or below the 50 μA criterion cut-off level, heightened

tenderness ratings of "3" or "4" assisted in the correct identification of a point as "reactive". Moreover, the region of the ear which was most tender was frequently associated with the area of the body where the patient reported the most severe discomfort; the current intensity at such sites was often no higher than that observed at other "reactive" ear points.

In addition to the identification of regions of the body where musculoskeletal pain was present, the results from the auricular diagnosis findings were also indicative of the side of the body on which the pain problem occurred. Although both the right and left auricular sites corresponding to a pathological area of the body tended to be "reactive", representation was usually greater on the ipsilateral ear. There were 59 instances wherein musculoskeletal pain was localized to just one side of the body. As shown by the mean auricular conductance values in Table IV, the ear points ipsilateral to the respective pathological area of the body were 72.4 μA. At the contralateral ear points corresponding to the same bodily areas, the mean conductance value was only 50.0 μA. The difference between ipsilateral and contralateral conductance values was significant by the t test for matched pairs ($P < 0.01$) [14]. On an individual comparison basis, for 47 (or 79.7%) of the 59 instances of lateralized musculoskeletal pain, the current intensity at the ipsilateral ear was greater than that recorded from the contralateral ear. This difference was also significant ($P < 0.01$, Sign test).

Subjective judgments of dermal tenderness at auricular loci were not as sensitive to the laterality of bodily problems. A mean dermal tenderness rating of 2.0 was found at ear points which corresponded to the same side of the body on which the pain problem was present. This value was only slightly greater than the mean dermal tenderness rating of 1.8 found at the contralateral ear points for the same bodily areas. An analysis of individual instances of unilateral body problems revealed that the dermal tenderness ratings were higher on the ipsilateral side of the body 25 times, on the con-

TABLE IV

MEAN ELECTRICAL CONDUCTIVITY AND DERMAL TENDERNESS DISTINGUISHED BY LATERALITY OF EAR POINTS RELATIVE TO SIDE OF BODILY PROBLEM

N = 59 paired comparisons.

		Established medical diagnosis	
		Ipsilateral bodily problem	Contralateral bodily problem
Mean auricular conductivity (0—300 μA)	$\bar{X}$	72.4	50.0
	S.D.	± 36.2 [a]	± 33.2
Mean auricular tenderness (0—4 scale)	$\bar{X}$	2.0	1.8
	S.D.	± 1.4	± 1.4

[a] Conductivity: matched pairs, $t = 5.00$, df = 58, $P < 0.01$.

TABLE V

MEAN ELECTRICAL CONDUCTIVITY AND DERMAL TENDERNESS DISTINGUISHED BY RECENCY OF BODILY PROBLEM

N = 316 recent or old bodily problem areas.

		Established medical diagnosis	
		Recent problem	Old problem
Mean auricular conductivity (0—300 μA)	$\bar{X}$	60.8	62.5
	S.D.	± 45.5	± 42.6
Mean auricular tenderness (0—4 scale)	$\bar{X}$	1.8	1.9
	S.D.	± 1.3	± 1.4

tralateral side of the body 15 times, and were the same in the remaining 19 comparisons. Thus, there was no significant trend with respect to the auricular tenderness ratings at ear points ipsilateral and contralateral to the side of body pathology.

There were 319 cases in which the bodily pain problem could be categorized as either recent (defined as occurring within 6 months prior to the study) or old (defined as those problems which began over 6 months before the study was conducted). In the remaining 81 cases, the pain problems were considered both recent and old, as when a patient reinjured a given area of the body. The findings displayed in Table V reveal that there were no marked differences in either auricular conductance or auricular tenderness between recent and old pain problems. It was just as likely for there to be elevations of electrical conductance and dermal tenderness at auricular sites related to bodily areas where the pain problem was due to an old limb fracture or back injury as when the bodily region represented was currently in a cast or body brace. Since none of the subjects was examined immediately after an accident, it is not possible to determine from these findings whether a very recent trauma would lead to a more striking increase in auricular "reactivity".

The final category considered in auricular diagnosis is the presence of morphological changes or pigmentation at particular ear loci. Of all 40 subjects examined in this study, there were only 6 instances of such alterations on the auricular skin surface. Wherever there was a localized region of white, flacky scaling on the dermis of the pinna, that auricular area represented a part of the body where musculoskeletal pain was present. Although infrequently observed, abnormal morphological characteristics on the auricular surface were highly predictive of the presence of pathology in the corresponding area of the body.

DISCUSSION

In the present study, enhanced tenderness and increased electrical conductivity at localized areas of the auricle exhibited highly significant corre-

spondence to areas of the body where subjects reported pain or some pathology. These findings thus support the clinically derived hypothesis that there is a somatotopic map arranged upon the external ear. Even with the clinical limitations imposed by the double-blind, experimental design, the physician conducting the auricular diagnosis achieved an accuracy of 75.2%, correctly differentiating "problem present" from "problem absent" areas of the body. It was also possible to predict the side of the body upon which the problem occurred, as the ipsilateral ear exhibited significantly greater conductivity than the contralateral ear. Such findings require a whole new approach towards the neurophysiological understanding of distant acupuncture points.

Several investigators have previously demonstrated that acupuncture points on the body exhibit lower skin resistance and higher skin conductance than adjacent areas of the skin surface [2,33,35]. Furthermore, the increase in electrical current found at body acupuncture points is even greater when those points are ipsilaterally related to bodily regions exhibiting known pathology [2]. Research studies not specifically oriented towards acupuncture have also provided relevant data. Those same regions of the skin surface from which a patient reports sensations of pain are also characterized as demarcated regions of diminished skin resistance [33,34]. Such alterations in skin conductivity at painful areas of the body have been attributed to regional hyperactivity of the sympathetic nervous system.

If pain-related autonomic activity can produce localized changes in skin resistance on the surface of the body, a similar process could certainly occur at the ear. In fact, decreased skin resistance at particular areas of the human and rabbit auricle has been observed following stimulation of different areas of the body [19]. Prolonged, sympathetic hyper-reactivity, which can affect both sweat gland activity and blood flow regulation, could account for the changes in scaliness and pigmentation observed at the ear. Localized autonomic reactivity, however, cannot account for the somatotopic aspects of auricular diagnosis. Anatomical studies by Bossy et al. [3], though, have shown that the auricle is differentially innervated by the trigeminal, facial, glossopharyngeal, vagus and superior cervical plexus nerves. They suggested that this differential innervation of the nervous supply to the pinna can indeed be related to the somatotopic map proposed by Nogier [32].

Neuroanatomists have known for some time that there is an orderly representation of localized areas of the body at specific areas of the brain [5]. Possible connections between the ear and the different parts of the somatotopically organized nuclei of the lemniscal system, the thalamus and the cerebral cortex remain to be determined. Of all these brain areas, the homuncular arrangement of evoked neural responses in the thalamus most corresponds to the inverted fetus pattern represented upon the ear. The classical work by Mountcastle and Henneman [30] showed that the head area is represented toward the ventromedial somatosensory thalamus, the foot is represented toward the dorsolateral somatosensory thalamus, and the body in between.

The proposition that a specific relationship exists between the thalamic homunculus and body acupuncture points has been previously suggested by Lee [20] and by Kroening and Donaldson [18]. The latter authors postulated that the process of lateral inhibition in adjacent, somatotopic zones of the thalamus does offer a neurophysiological explanation for distant acupuncture points. Excitation of somatosensory specific thalamic neurons could also interact with other brain stem systems, such as the descending pain inhibitory pathways demonstrated by Liebeskind et al. [26]. That stimulation of the auricle could affect such a brain stem system is indicated by the work of McCreery and Bloedel [28]. They demonstrated that activation of trigeminal input could suppress the nociceptive responses of spinothalamic neurons located in the lumbosacral spinal cord. More direct support for this proposed relationship between the homuncular representation on the auricle and the somatotopic organization of the brain will require neurophysiological research designed to specifically examine this issue.

The present findings do have important clinical implications for the treatment of pain. Demonstration of the validity of auricular diagnoses does provide clear evidence for the existence of a system of distant acupuncture points. These results were obtained under experimentally controlled conditions which were not influenced by patient placebo responses or the hypnotic suggestibility of the subjects, arguments often cited to discount the treatment effects of acupuncture. Auricular diagnosis itself would not seem to be of particular practical significance, since it would be easier to ask patients where they experienced musculoskeletal pain than to examine their ears. However, in cases where such communication is not available, such as in comatose patients or small children, auricular diagnosis could prove to be of some usefulness.

This study also indicated that the auricular diagnosis technique is often sensitive to pathological problems of which the patient is only minimally aware. When some patients were told of their auricular diagnosis results, they suddenly remembered having a minor or old pain problem in that bodily area, a problem which they had neglected to mention during the medical evaluation. Since these post-hoc results were derived after the ear diagnosis had been made, these instances were not included in any statistical analyses. Nonetheless, such observations do suggest that auricular diagnosis may be effectively employed as part of a general medical evaluation designed to reveal all organic aspects of a patient's pain complaints. Since there are also ear points for abdominal and thoracic bodily organs [15,38,40], auricular diagnosis could also be utilized with standard diagnostic procedures for analyzing pathological conditions related to internal pain or referred pain.

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