Detecting facial paralysis in patients with Bell's palsy by comparing bilateral measurements of facial temperature

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Detecting facial paralysis in patients with Bell's palsy by comparing bilateral measurements of facial temperature

A Masters Thesis

Submitted to the Department of Medicine

and the Graduate School of Yonsei University

in partial fulfillment of the

requirements for the degree of

Master of Medicine

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December 2021

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December 2021

감사의 글

전공의 수련과정의 수료와 같은 시기에 석사 과정을 마무리하고 학위 논문을 제출하게 되었습니다. 학사를 마치고 들어온 새내기 의사가 석사 학위를 가진 전문의가 되기까지 교육하시고 도움을 주신 부모님, 선생님들, 그리고 선·후배님들께 감사의 말씀을 전하고자 합니다.

먼저 석사 과정을 마칠 수 있도록 힘이 되어주신 부모님께 감사드립니다.

본 논문이 완성되기까지 지도와 격려를 아끼지 않고 이끌어 주신 서영준 교수님께 진심으로 감사드립니다. 또한 논문 심사 과정에서 아낌 없는 조언으로 많은 가르침을 주신 정순희 교수님, 공태훈 교수님께도 진심으로 감사드립니다. 또한 전공의로서 임상 지식을 가르쳐주시고 석사 과정에서 이를 활용할 수 있도록 도움 주신 봉정표 교수님, 박동준 교수님, 박상유 교수님, 이은정 교수님을 비롯한 이비인후과 교실의 교수님들께 감사드립니다.

연구를 하는 데에 있어 도움을 준 이비인후과 의국원 선·후배님들에게도 감사드립니다.

이 외에도 학업 과정에서 저를 지지해주고 아이디어를 생각나는 데에 있어 도움을 준 친구들과 도움을 주신 모든 분들께도 진심으로 감사드립니다. 석사 과정은 끝나지만 여기서 안주하지 않고 더욱 발전하는 모습으로 성장하는 의사가 되겠습니다.

감사합니다.

2021 년 12 월

전 현 종 드림

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ABSTRACT

Detecting facial paralysis in patients with Bell’s palsy by comparing bilateral measurements of facial temperature

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Introduction: Bell's palsy is one of the most common causes of peripheral facial palsy. It manifests as paralysis of the facial nerve, which can lead to changes in the affected side’s surface temperature of the face. Currently, commonly used evaluation tests for facial paralysis include nerve electromyography and electromyography, which require skilled examiners and devices. If facial paralysis can be evaluated through facial temperature measurement, it can be evaluated more easily. Until now, there was no standardized environment to measure facial temperature, so researchers had to make their own standards, and the measurement environment was different for each study, making it difficult to conduct complex studies.

Methods: A total of 19 patients admitted to the Department of Otorhinolaryngology-Head and Neck Surgery, Wonju Severance Christian Hospital with Bell's palsy from July 2020 to April 2021 were enrolled. The patient's facial temperature was measured at six regions of interest (frontalis,

oculi, zygomaticus, nasalis, oris, and marginal area) in a controlled environment. The temperatures of the affected and non-affected sides were compared. Clinical evaluation of facial palsy was assessed using the House-Brackmann grading system.

Results: Among the six regions, the non-affected side of nasalis and oris regions showed higher temperatures than the disease side, and the one-sample T-test showed statistically significantly higher temperatures on the non-affected side than on the affected side($p = 0.038$ for nasalis region and $p = 0.049$ for oris region).

Discussion: Facial paralysis can be detected in patients with suspected facial palsy by measuring and compairing the temperature of the nasalis and oris regions.

Key words : Facial palsy, Bell's palsy, Thermography, Infrared thermal imaging

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I. Introduction

Facial nerve palsy is largely divided into central facial nerve palsy and peripheral facial nerve palsy. About 80% of patients affected by facial nerve palsy have peripheral facial nerve palsy.[1] Bell's palsy is the most common form of peripheral facial nerve palsy with an annual incidence of 15-40 per 100,000 people. The disease is so common that 1 in 60 people experience it during their lifetime.[2] Facial palsy causes immediate functional deformation and discomfort which leads to decreased quality of life, and psychological pain. During the course of treatment, the patient can observe that their palsy state is improving as symptoms improve. However, there are cases where the physician or the patient themselves require an objective evaluation of the degree of palsy. Thus, studies have been conducted using various methods to measure the degree of paralysis and prognosis.[3-5]

Thermography is a non-invasive and radiation free imaging method used to measure minute changes in the temperature of various parts of the body. It allows the objective visual confirmation of the disease state.[6] One of the important theoretical fundamental principles of thermography is that the distribution of body heat is symmetrical in the human body. The temperature difference is considered normal when the average difference is within 0.3℃.

The first recorded use of thermography started Hippocrates who measured temperature distribution by applying mud to patients' bodies and watching it dry. Leo Massopurt applied thermography to clinical practice in 1948, and Ray Lawson used it for the diagnosis of breast cancer in 1956.[3,7,8]

Thermography has been used for imaging breast disease, autonomic nervous system disease, peripheral nerve injury, musculoskeletal disease,

and cerebrovascular disease, as well as for cancer screening and confirmation of pain before and after surgery.[9]

Song conducted facial thermography on 89 patients with Bell's palsy, and measured facial temperature at disease onset, and at various periods during treatment. Song reported that the temperature difference can be used as a criterion for clinical prognosis.[10] Son et al analyzed the correlation between the severity of Bell's palsy and facial temperature using the House-Brackmann grading system.[11] It has recently been shown that infrared-based facial temperature measurements are affected by climatic conditions. For example, it has been shown that increasing air temperatures from 15.5ºC to 26.6ºC caused the inner canthi surface to increase from 35.7ºC to 37.6ºC, even though deep body temperature remained unchanged.[12] Such findings clearly demonstrate that it is important to control the environment for imaging during thermography.[13] When the temperature and humidity of the environment are stable and there is no wind, the skin temperature of the face is maintained.[14]

So far, studies measuring facial temperature using thermography used different environmental conditions which creates problems with reliability and low specificity. Because there is no specific set of standards or guidelines for environmental regulation during thermography, each study set different conditions when conducting thermography. Therefore, in the current study, to predict the prognosis of facial palsy through facial thermometry in patients with Bell's palsy, the authors measured facial temperature in the same regions and under the same environmental conditions presented by the Data Center for Korean Body Temperature's guidelines. The House-Brackmann grading system was used as an index to evaluate the severity and predict the prognosis of the patients with Bell's palsy.

II. Materials& Methods

1. Patient selection

A total of 19 patients were enrolled. Patients attended the Department of Otorhinolaryngology-Head and Neck Surgery, Wonju Severance Christian Hospital with peripheral facial palsy and were diagnosed with Bell's palsy from July 2020 to April 2021. All patients had brain CT, brain MRI, or temporal MRI to rule out other diseases that could cause facial palsy. Patients did not take corticosteroids prior to their admission. Existing self-medication was taken as scheduled, but in principle, measured before taking oral steroid medicine. Doctors obtained the informed consent of all patients before examination.

2. Examination methods

A. Thermography instrument

An infrared thermography device was used to measure the temperature of the body surface. The device was a demonstration device which is not commercially available. (Manufactured by M.I One, Wonju, Republic of Korea)

B. Examination environmental conditions

a. Thermography was conducted in a room with blinds to block outside light and heat. A constant environment of 24-26°C and humidity of 60% were maintained with an air conditioner.

b. Subjects were exposed to certain environmental conditions for 15

minutes until breathing and heart rate stabilized with no sweating.

C. Temperature measurement sites

The anterior face was imaged while the patient was seated in a chair. The temperature at 15 sites was measured according to the Korean Body Temperature Data Center's guidelines which detail the standard temperatures of various points of the body of Korean adults. The 15 sites were classified as belonging to the frontalis, oculi, nasalis, zygomaticus, alar, oris, and marginal regions based on the distribution of the facial nerve branch and superficial facial muscles. The exact temperature measurement site was determined as a universal value in the region of interests (ROI) (Figure 1).

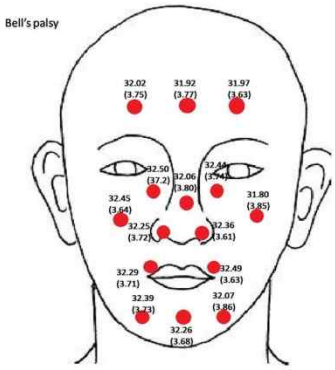

Figure 1. Regions of interest where facial temperature was measured. Sites were facial temperature were measured corresponding with the sites presented by the Data Center for Korean Body Temperature.

3. Diagnostic method

The degree of facial palsy was evaluated using the House-Brackmann grading system, which is a clinical tool for evaluating facial palsy. The House-Brackmann grade of each of the study subjects was evaluated by one

evaluator (Professor Seo Young-Joon).

4. Statistical processing

Statistical processing was performed using the SPSS 28. Statistically, the third decimal place was rounded off and only the second decimal place was displayed. Intra-subject variability in the bilateral temperature difference was ascertained by dividing the temperature of the affected side and the non-affected side, and the difference was determined by subtracting the value of the affected side from the non-affected side. A p-value <0.05 was considered statistically significant.

III. Results

1. Sex, age, side of paralysis, and period from paralysis onset to hospital visit

Among the 19 patients, the male to female ratio was 10 and 9. The average age was 57 (±17.76) years old. Nine patients had right-sided facial palsy (47.37%) and ten patients had left-sided facial palsy (52.63%). The mean period from the time of onset of facial palsy to hospital visit was 2.53 (± 1.93) days (Table 1).

Table 1 General information of subjects

Age	Gender (n)		Site of disease (n)		Onset to visit
(mean ± SD, years)	Male	Female	Right	Left	(days)
57 ± 17.76	10	9	9	10	2.53 ± 1.93

2.Initial degree of paralysisevaluated by the House-Brackmann grading system

The initial House-Brackmann grade was grade IIin fivepatients (26.32%), grade IIIin thirteenpatients (68.42%), and grade IVin onepatient (5.27%)(Table 2).

Table 2 Ratio by House-Brackmann grade

Grade	Number (n)	Ratio (%)
1	0	0
2	5	26.32
3	13	68.42
4	1	5.27
5	0	0

3. Facial temperature at each site of the face

Facial temperature was measured at the same 15 sites as presented by the Data Center for Korean Body Temperature measuring normal adult temperature. The lowest average temperature was 31.8°C in the left zygomaticus area; and the highest average temperature was 32.5°C,in the right oculi area (Table 3).

Table 3 Regional mean temperature without considering the site of disease

Site (mean ± SD, °C)	Right	Mid	Left
Frontalis	32.02±3.75	31.92±3.77	31.92±3.77
Oculi	32.50±3.72[a]		32.44±3.74
Nasalis	32.25±3.72	32.05±3.81	32.36±3.61
Zygomaticus	32.45±3.64		31.80±3.85[b]
Oris	32.29±3.71		32.49±3.63
Marginal	32.39±3.73	32.263.68	32.07±3.86

a. Right Oculi area was the highest temperature site and b. Left Zygomaticus area was the lowest temperature area.

When divided into affected and non-affected sides, the highest average

temperature was 32.53°C which was recorded in the oculi area of the non-affected side, and the lowest was 31.98°C which was recorded in the frontailis area of the affected side (Table 4).

Table 4	Mean temperature (°C)	
Site	Disease side	Control side
Frontalis	31.98	32.01
Oculi	32.41	32.53
Nasalis	32.10	32.15
Zygomaticus	32.18	32.44
Oris	32.28	32.50
Marginal	32.22	32.24

The data was obtained and expressed as a figure by subtracting the temperature of the affected side from the non-affected side at six sites measured bilaterally. A positive value was shown, confirming that the affected side generally had a lower temperature regardless of the regions. Generally, the non-affected side had a higher temperature than the affected side (Figure 2).

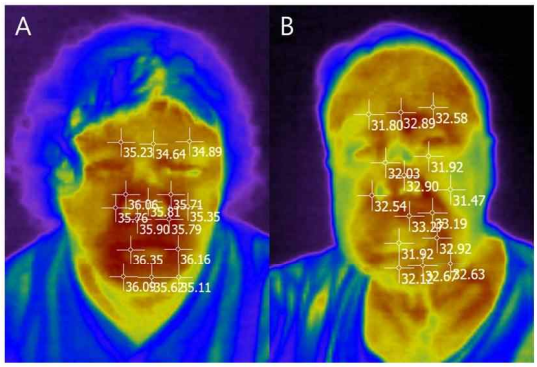

Figure 2.
Facial temperature of patients with (A) left-sided facial palsy and (B) right sided facial palsy. In general, the non-affected side showed higher temperature than the affected side."

The nasalis area had the largest difference in temperature between sides, and the marginal area had the smallest difference between sides (Figure 3A).The value obtained was corrected by subtracting the temperature of the non-affected side from that of the affected side using standard data from the Korean Body Temperature Data Center. The marginal area showed little difference in the temperatures of each side. This tendency was also seen in other areas (Figure 3B). The nasalis and oris areas still had a higher temperature on the non-affected side than the affected side. One sample t-test was performed under the premise that there was no temperature difference between the two sides in a healthy person without facial paralysis. It showed thatthe temperature was statistically significantly higher in the non-affected side than the affected side ($p=0.038$ for the nasalis area and $p=0.049$ for the oris area).

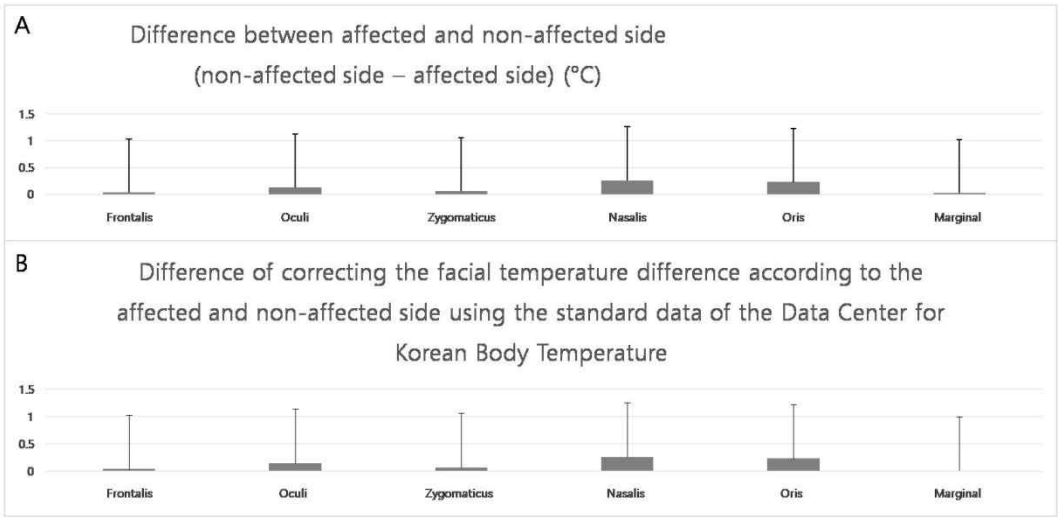

Figure 3.
(A)The diffenece between affected side temperature and non-affected side temperature along the measurement region
Because the difference is positive value, the affected side shows a lower body temperature than the non-affected side regardless of the sites.
Nasalis region was the highest difference between the affected and non-affected side, 0.26°C (± 0.50°C)
Marginal region was the lowest difference between the affected and non-affected side, 0.02°C (± 0.66°C)
(B) Difference of correcting the facial temperature difference according to the affected and non-affected side using the standard data of the Data Center for Korean Body Temperature.
Little difference between the affected and non-affected side in the marginal region, and the tendency was maintained in other regions.

4. Prognosis according to difference of temperature

To predict prognosis, patients were divided into 'improved' or 'non-improved' groups based on whether their facial palsy improved during the two-month outpatient follow-up period. The temperature difference between the affected and non-affected sides was compared between improved and non-improved groups. The improved group showed lower temperature on the non-affected side than the affected side in all regions of interest except the frontalis area and marginal area (Figure 4).

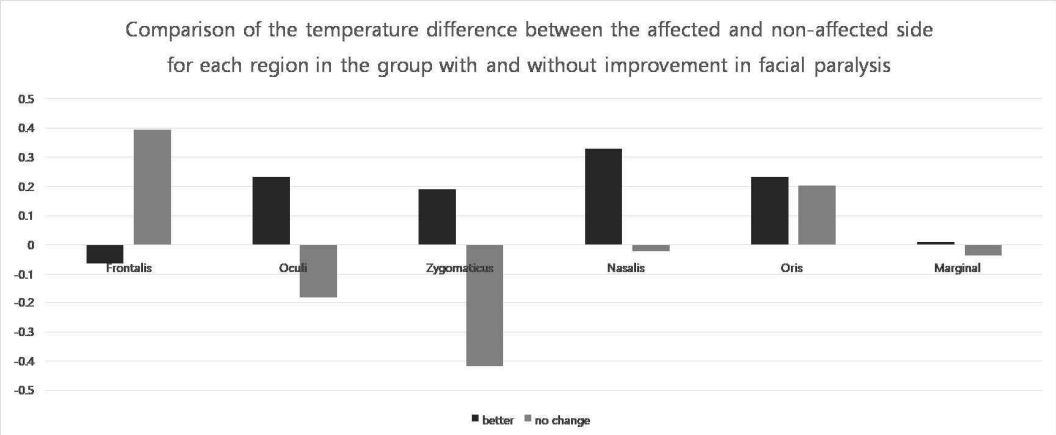

Figure 4. Improved group showed a lower body temperature at the control side than disease side, but this tendency was not evident in the frontalis and marginal regions.

5. Differences of temperature depending on House-Brackmann grade

To analyze whether the temperature differential between the affected side and the non-affected side was meaningful according to the initial House-Brackmann grade, patients was divided into three groups by initial House-Brackmann grade: HB-G II (n=5), HB-G III (n=13), and HB-G IV (n=1). The temperature differential was determined by subtracting the temperature of the non-affected side from the affected side and was compared among each group. The nasalis and oris areas showed a negative value regardless of the group. However, for the zygomaticus area, positive values were shown in the HB-G II and HB-G IV groups. In the HB-G IV group, the marginal area showed a positive value, but the sample size (n=1) was too small considered to be significant (Figure 5).

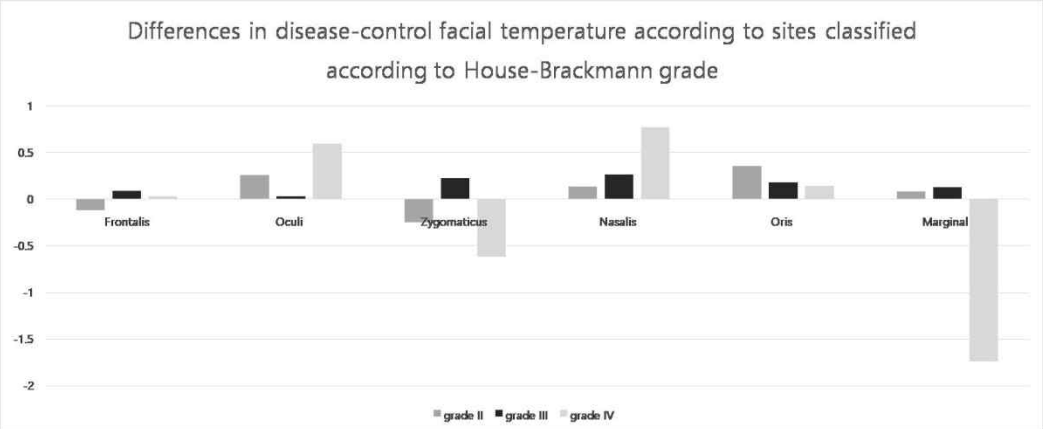

Figure 5. Oculi, nasalis, and oris regions showed a negative value regardless of the group. In the case of the marginal region, positive values were shown in the HB-G IV group, but the sample size was not considered to be a significant result value as 1 patient.

6. Factors that affect facial skin temperature.

In patients with facial paralysis, the affected side had lower temperature, and the values were different depending on the site measured. This may be due to the skin thickness in the various ROIs: a larger temperature change may occur in an area with thin skin, and lower temperature change may occur in an area with thick skin. To test this theory, the correlation between facial skin thickness and temperature was confirmed using the index measured by Richard Y Ha. et al.[15]A larger temperature change was found in the oculi, nasalis, and oris regions where the skin thickness is relatively thin, but linear regression test showed no statistical significance.

Aging is associated with changes in the mechanical and structural properties of the vascular wall which leads to the loss of arterial elasticity and reduced arterial compliance.[16] To determine whether the change in temperature decreases or increases in elderly patients, patients were divided into two groups, over 60 and under 60. Again, no statistically significant differences

were found regardless of the ROI tested.

IV. Discussion

This study measured the facial temperature of patients with Bell's palsy and compared the temperatures of the affected and non-affected sides of the face, based on previous study. We found no statistically significant difference when simply comparing the temperature of the affected and the non-affected sides of the face, due to differences in temperature between individual patients caused by individual basal temperature or disease history. To correct for individual differences, for each patient, the temperature of the non-affected side was subtracted from the temperature of the affected side. In the nasalis and oris areas, the affected side showed a statistically significantly lower temperature than that of the non-affected side. Initial facial temperature measurement in the nasalis and oris regions of patients with suspected facial paralysis may facilitate the confirm of facial paralysis. In this study, statistical significance was obtained even with a small number of samples, but it is necessary to increase the validity of these results by conducting further studies with a larger number of samples.

After calibration using standard data from the Data Center for Korean Body Temperature, the marginal area showed little difference between the affected side and the non-affected side. Thus, the temperature of the marginal area can be used to indicate whether an appropriate environment is being maintained during the thermography procedure.

Electroneurography (ENoG) and electromyography (EMG) are currently used to evaluate the degree of facial paralysis or predict prognosis among patients with Bell's palsy. However, these tests require equipment and electrodes that need to be attached to the patient's skin at appropriate locations. Thus, an experienced technician, such as a medical laboratory

technologist, is required. It is difficult to perform an examination in a hospital without a technician available. On the other hand, there are several benefits to detecting and predicting prognosis using facial temperature alone: An experienced technician would not be required. In addition, no specialized thermal imaging tools would be needed for the examination, which would considerably reduce both initial investment and maintenance costs. Therefore, if facial paralysis can be detected or evaluated through facial temperature measurement and follow-up studies, a facial thermography approach could be more widely applied than current electroneurographic methods.

However, facial thermography is not necessarily superior to existing tests such as ENoG and EMG. Because thermography equipment measures the surface facial temperature using a non-contact method, results may be affected by the measurement environment. It may be difficult to maintain a constant environment in the examination room. In addition, the accuracy of the results may be influenced by patient factors such as medical history which can change the skin's surface temperature, or use of medications such as steroids or vasoconstrictors which can cause temperature changes.

Despite these shortcomings, this study may be expandable. Future research may differentiate other diseases and predict prognosis using a similar a non-contact method with similar equipment to measure body temperature or extremity temperature.

V. Conclusion

In this study, because the patient's facial temperature was measured only once at the time of hospitalization for treatment of Bell's palsy, the changes in facial temperature over time could not be ascertained. Thus, changes in facial temperature and the relationship between prognosis and facial temperature during the recovery process were not analyzed. This could be supplemented in a follow-up study by measuring the facial temperature during outpatient follow-up and performing additional analysis. Also, this study was conducted with a total of 19 patients which was insufficient to verify the effectiveness of the method. By including a larger number of participants in a follow-up study, it will be possible to analyze the temperature differential according to disease severity and the age of patients in more detail.

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국 문 요 약

벨 마비 환자의 양쪽 안면 체온 측정을 통한 안면 마비의 감지

벨 마비는 말초성 안면 마비의 가장 흔한 원인 중 하나로 안면 신경 마비로 나타나 얼굴의 표면 온도를 변화시킬 수 있다. 현재 보편적으로 사용되는 안면마비의 평가 검사로는 신경근전도검사, 근전도검사 등이 있는데, 숙련된 검사자와 기기가 필요하다. 얼굴 온도 측정을 통해 얼굴마비의 평가가 가능하다면 더 쉽게 사용이 가능하다. 여태까지의 연구에서는 얼굴 온도를 측정하는 표준화된 환경이 없어 연구자들이 각자의 기준을 만들어야 하고, 연구별로 측정 환경이 달라 복합연구에 어려움이 있었다. 2020년 7월부터 2021년 4월까지 벨 마비로 원주세브란스기독병원 이비인후-두경부 외과에 입원치료 한 총 19명의 환자를 대상으로 약물 치료 전 통제된 환경에서 환자들의 안면 체온을 측정하였고 이를 6개의 영역으로 나누어 마비 측과 정상 측의 온도를 비교하였다. 안면 마비 정도의 임상적인 평가는 House-Brackmann grade를 사용하였다. 6개 영역 중 비근부 및 입둘레근 영역에서는 대조군 측이 질병 측 보다 높은 온도를 보였고, 일표본 T-검정을 수행한 경우 질병 측 보다 대조군 측에서 통계적으로 유의하게 높은 온도를 나타내었다(비근부 영역의 경우 p-value 0.038이고 입둘레근 영역의 경우 p-값이 0.049로 통계적으로 유의하였음). 안면 마비가 의심되는 환자

의 경우 비근부와 입둘레근 부위의 온도를 확인하여 안면 마비를 감지할 수 있을 것으로 기대한다.

핵심되는 말 : 안면 마비,벨 마비,체열검사,적외선 체열 이미지

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