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Developing an Effective Quantification Method of Tongue Deviation Angle to Assess Stroke Patients

Ching-Chuan Wei [1], Sheng-Lin Hsu [2]

[1] Chaoyang University of Technology
[2] ccwei@cyut.edu.tw, xhrokttn@gmail.com

Abstract. In this study, we developed a simple and effective method to assess stroke subjects using the angle of tongue deviation. We designed an experiment to identify whether the method is effective. The means and standard deviations of the tongue angle of the experimental and control groups are 2.1 ± 0.6 and 5.7 ± 1.8 degrees, respectively. Analyzed by Student's t-test, the p value (< 0.01) shows the significant difference in this parameter between the experimental and the control groups. This implies that the tongue deviation angle can effectively identify the normal and stroke subjects. The results confirm the feasibility of future use of the tongue deviation angle as an early warning of the occurrence of stroke in telehealth.

Keywords: Tongue diagnosis angle, Stroke, Telehealth

1. Introduction

In Western medicine, the tongue can exhibit information pertaining to disease, especially in the case of stroke. The tongue has always been one of the important organs providing health status indicators and physical information about the human body in traditional Chinese medicine (TCM). Many diseases will cause variations in the color of the tongue body and tongue coating, as well as in the tongue shape in TCM [1]. Because the tongue image is easily observable at home, it is an excellent choice to be used in home healthcare. Thus, if we can quantify the features of the tongue and scientifically verify the relationship between the tongue and disease, the information provided by the tongue will be helpful in telemedicine, which integrates Western medicine and TCM.

Stroke, a cerebral vascular incident, is mainly caused by abnormal blood vessels in the brain. Stroke often occurs suddenly. According to the statistical results of World Health Organization (WHO), stroke remains the worldwide second leading cause of death. It is estimated that one in five stroke survivors will have the chance of a second stroke within five years. So, it has a high recurrence rate, and recurrence can bring about disability and dementia, often leading to a heavy burden for an individual household, a community, and ultimately society in general. This reminds us how important it is to prevent and monitor the stroke subject.

Thus, if we can find the physical tongue indicators of an oncoming stroke in advance, we may prevent the actual event. Stroke will produce changes in the body and affect various functions, including the sensory function, action function, language ability, the swallowing function, etc. Most stroke patients will show the crooked-tongue symptom recognized by both Western medicine and TCM [2]. The tendency of the tongue to turn away from the midline when extended or protruded is called tongue deviation. The condition is associated with a hypoglossal nerve defect, causing the tongue to deviate to the side of the injured nerve. The tongue is a sensitive area within the human body because of its many neural controls. Consequently, even minor nerve damage resulting from a stroke may have a significant impact on the shape and motion of the tongue.

Some researchers have developed complex methods to quantify the crooked tongue [3]. In this study, we developed a simple and effective method to quantify the deviation of the crooked tongue. Then, we conducted the experiment on stroke patients to verify the feasibility of our quantification method to assess the stroke subjects.

2. Methods

2.1. Tongue image acquisition and edge segmentation

We built a brace rack to support the chin in order to fix the tongue position, as shown in Fig. 1. Then, we took a picture of the subject's tongue using a digital camera and a circular light source, which uniformly distributes the light on the tongue, as shown in Fig. 2. Next, using the threshold method and Otsu's Algorithm for edge segmentation, we removed skin, tooth, lip, background, etc., and then obtained the pure tongue image, as shown in Fig. 3 [4–7]. In the following steps, we will start to quantify the angle of tongue deviation.

Fig. 1: The setup diagram for obtaining the tongue image

Fig. 2: The tongue image

Fig. 3: The pure tongue image through edge segmentation

2.2. Quantifying the angle of tongue deviation

2.2.1 Locating the root point

The first step is to locate the root point of the tongue, which is defined as the center point at the bottom of the tongue. Before locating the root point, the left side and right side points of the tongue bottom should be found. These two points were searched using the oblique angle method, described in the following and demonstrated in Fig. 4(a).

1. The searching order of the left oblique starts from point (0,0), and then (0,1), (1,0), (0,2), (1,1), (2,0), etc, until the first point in the red part is found. The first point is called the left oblique point.
2. The searching order of the right oblique starts from the top right point (m, n), and then (m-1, n), (m, n-1), (m-2, n), etc, until the first point in the red part is found. The first point is called the right oblique point. The middle point between the left and right oblique point is defined as the root point of the tongue. It is shown as a star point in Fig. 4(b) and marked as symbol "A."

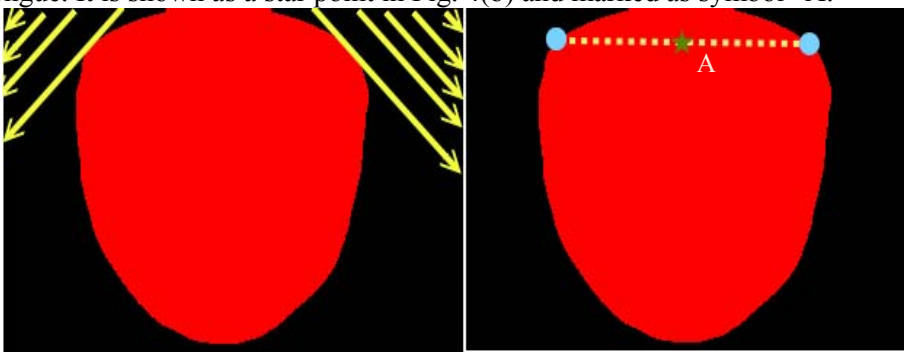


Fig. 4: (a) The searching order (b) The root point of the tongue

2.2.2 Locating the center point

The method of finding the tongue center point is detailed in the following:

1. The value of the vertical coordinate of the tongue center point is derived by the value of the vertical coordinate of the middle point between the top and end points of the tongue, as shown in Fig. 5.
2. As soon as the vertical position of the center point was found, the horizontal position was derived by the horizontal value of the middle point between the left and right points of the tongue, as shown in Fig. 5. Then, the center point of the tongue was determined; it was marked as symbol "B." The tongue center point means the center of the tongue; it may deviate with an angle compared to the vertical line in stroke patients, as shown in Fig. 6.

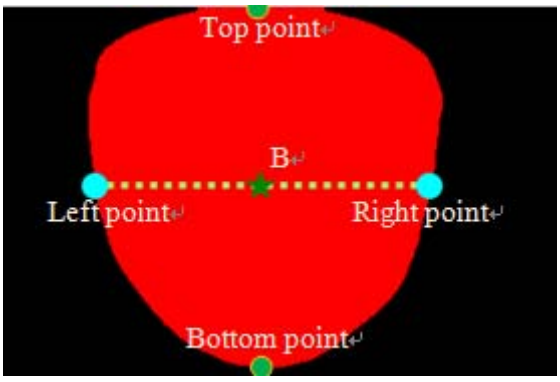


Fig. 5: Marking the center of the image base of the tongue

2.2.3 Evaluating the tongue deviation angle

The value of the vertical coordinate of point C in Fig. 6 is equivalent to that of point B, and the value of the horizontal coordinate of point C is equivalent to that of point A. Thus, point C is defined, and ∠C in Fig. 6 forms a right angle, and ∠A in Fig. 6 is the tongue deviation angle used to assess the stroke patients.

The distance between point B and point C is defined as a; the distance between point A and point C is defined as b. Then, ∠A is calculated by the following:

$$\angle A = \tan^{-1}\frac{a}{b} \tag{1}$$

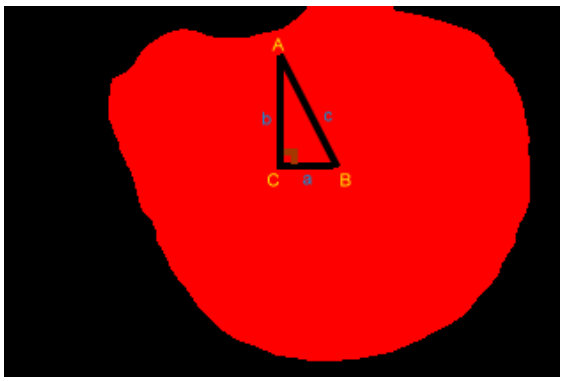


Fig. 6: The tongue image of a stroke patient, and the related points

3. Experiment and Results

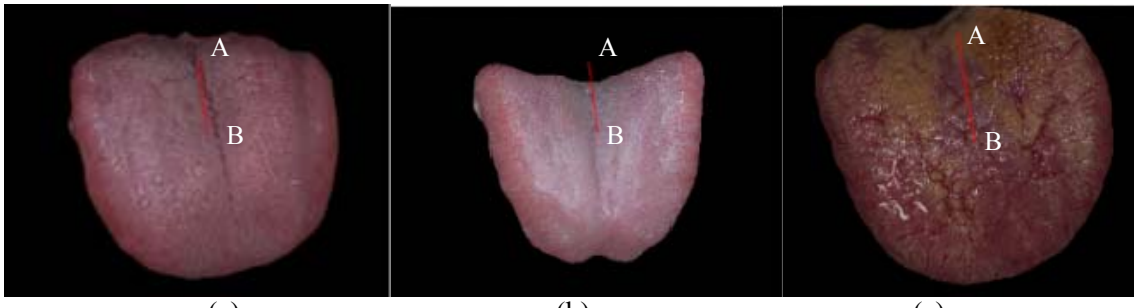
The members of the experimental group of 20 stroke subjects, ranging between 56 and 81 years of age (16 males and 14 females), were subjected to the measurements of the tongue image from 8/15/2011 to 10/5/2011. Those in the control group, comprising 20 normal subjects with no stroke and ranging between 52 and 80 years of age (17 males and 13 females), were measured for comparison. The experiment protocol was approved; written informed consent was obtained from all of the participants before they enrolled in this study.

The tongue images of two normal subjects are shown in Figs. 7(a) and (b). Their corresponding tongue deviation angles, calculated by Equation (1), are 0.74 and 0 degrees, respectively. There are almost no tongue deviations in the two subjects.

(a) (b)

Fig. 7: (a), (b) The tongue images of the normal subjects

Fig. 8 shows the tongue images of three typical stroke subjects. The calculated deviation angles are 7.2, 9.1 and 10.0 degrees, respectively. They show significant deviation.



(a) (b) (c)

Fig. 8 (a)–(c): The tongue images of stroke subjects

The means and standard deviations of the experimental and control groups are 2.1 ± 0.6 and 6.5 ± 1.8 degrees, respectively. Analyzed by Student's t-test, the p value (< 0.01) shows the significant difference in this parameter between the experimental and the control groups. This implies that the spring constant can effectively identify normal and stroke subjects.

4. Conclusions

In this study, we develop a simple and effective method to assess the angle of the tongue deviation for stroke subjects. The experiment comparing normal and stroke subjects shows the method's effectiveness. Because of the method's simplicity, it may be applicable in homecare or telehealth to present the early warning of the occurrence of stroke.

5. References

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