



Contents lists available at ScienceDirect

Journal of Traditional and Complementary Medicine

journal homepage: <http://www.elsevier.com/locate/jtcme>

## Exploring the pivotal variables of tongue diagnosis between patients with acute ischemic stroke and health participants



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### ARTICLE INFO

#### Article history:

Received 13 January 2022

Received in revised form

1 April 2022

Accepted 4 April 2022

Available online 7 April 2022

#### Keywords:

Traditional Chinese medicine (TCM)

Tongue features

Automatic tongue diagnosis system (ATDS)

Acute ischemic stroke

### ABSTRACT

**Background and aim:** Stroke is a major cause of disability worldwide, and ischemic stroke is the most common type of stroke. The prevention and treatment of ischemic stroke remain a challenge worldwide. Traditional Chinese medicine (TCM) is often sought to provide an alternative therapy for the prevention and rehabilitation intervention of ischemic stroke in Taiwan. Therefore, this study explored the pivotal variables of tongue diagnosis among acute ischemic stroke and healthy participants in middle and older age.

**Experimental procedure:** This was a cross-sectional and case-controlled study. Data were collected from 99 patients with acute ischemic stroke and 286 healthy participants who received tongue diagnoses at Changhua Christian Hospital (CCH) from September 1, 2014, to December 31, 2016. Tongue features were extracted using the automatic tongue diagnosis system. Nine tongue features, including tongue shape, tongue color, fur thickness, fur color, saliva, tongue fissures, ecchymoses, teeth marks, and red spots were analyzed.

**Results and conclusion:** Objective image analysis techniques were used to identify significant differences in the many tongue features between patients with acute ischemic stroke and individuals without stroke. According to the logistic regression analysis, pale tongue color (OR:5.501,  $p = 0.001$ ), bluish tongue color (OR:4.249,  $p = 0.014$ ), ecchymoses (OR:1.058,  $p < 0.001$ ), and tongue deviation angle (OR:1.218,  $p < 0.001$ ) were associated with significantly increased odds ratios for acute ischemic stroke. The research revealed that tongue feature abnormalities were significantly related to the occurrence of ischemic stroke.

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### 1. Introduction

Stroke is the second leading cause of death and the third leading cause of disability worldwide.<sup>1–3</sup> In addition, the trend of stroke incidence is increasing annually.<sup>4</sup> More than 13.7 million patients

were diagnosed with a stroke, accounting for 5.5 million deaths, 87% of which were due to ischemic cerebral infarction.<sup>5–7</sup> There has been considerable development in stroke treatment, including management of risk factors, reperfusion, rehabilitation, and neuronal protection and repair.<sup>8</sup> Despite medical advances, the

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Peer review under responsibility of The Center for Food and Biomolecules, National Taiwan University.

### List of abbreviations

Traditional Chinese medicine (TCM)  
 automatic tongue diagnosis system (ATDS)  
 Institutional Review Board (IRB)  
 Institutional Review Board (IRB)  
 body mass index (BMI)  
 odds ratio (OR)

disability rate after stroke remains high; therefore, prevention is essential. The known risk factors of stroke include age, gender,<sup>9</sup> hyperlipidemia,<sup>10</sup> hyperglycemia, hypertension,<sup>11</sup> cardiovascular diseases,<sup>12</sup> atrial fibrillation (AF),<sup>13</sup> etc. If the risk factors can be controlled at the early stages to reduce the incidence of stroke, the harm stroke brings to people can be greatly reduced.<sup>14,15</sup>

Traditional Chinese medicine (TCM) has been used for patients with stroke for thousands of years. TCM physicians evaluate clinical signs and symptoms using four diagnostic methods; namely, inspection, hearing and smell, questioning, and pulse examination and palpation. Tongue diagnosis serves as a common non-invasive means to reliably provide clinical information and plays a pivotal role.<sup>16,17</sup> Clinically, TCM physicians observe tongue features, such as the tongue color and shape, fur color and thickness, and the amount of saliva, to deduce the primary ailment of patients.<sup>18,19</sup> These factors have a significant impact on treatment and prognosis.<sup>20,21</sup> The automatic tongue diagnosis system (ATDS) has shown high consistency and can provide objective and reliable information based on the analysis of tongue features, thereby assisting doctors in making effective observations and diagnoses of specific diseases.<sup>22,23</sup> Several studies have used computerized tongue analysis to evaluate the relationship between tongue manifestations and various diseases, including gastroesophageal reflux disease,<sup>24</sup> diabetes mellitus,<sup>25</sup> metabolic syndrome,<sup>26</sup> and dysmenorrhea.<sup>27</sup>

However, there are relatively few studies on the application of tongue diagnosis applying to stroke.<sup>28</sup> One study used the tongue deviation angle to assess the severity of the stroke, for example, a tongue deviation angle more than the optimum threshold value ( $= 3.2^\circ$ ) predicts the risk of stroke.<sup>29</sup> Nevertheless, studies using TCM tongue features to evaluate stroke are relatively rare. This is the study in applying TCM tongue diagnosis for comparing the difference between patients with acute ischemic stroke (2–7 days) and healthy individuals among middle-aged and older adults ( $\geq 40$ -year-old).<sup>30,31</sup> This is the study in applying TCM tongue diagnosis for comparing the difference between patients with acute ischemic stroke and healthy individuals.

## 2. Methods and materials

### 2.1. Ethics approval and consent to participate

All the candidates underwent a standardized interview process. Participants were introduced to the purpose, procedures, potential risks, and benefits of the study first, following which they provided informed consent. This study was approved by the Institutional Review Board (IRB) of Changhua Christian Hospital (CCH), Taiwan (IRB reference numbers: 150110 and 140704).

### 2.2. Study design and participants

This was a case-control and cross-sectional study. This study recruited patients with acute ischemic stroke admitted to the CCH from March 2015 to December 2015, and excluded health

participants without a clear tongue image. The inclusion and exclusion criteria for this study were as follows:

#### Inclusion criteria:

1. Patients older than 40 years of age, who acted in concert with the complete examination and answered the questionnaire.
2. Participants were diagnosed as ischemic stroke (ICD-9:433–438) by neurologist, and were approved by head CT or MRI examination.
3. Those with a stable vital sign after being examined by an internal medicine specialist.
4. Those who experience a cerebral vascular accident within 10 days of the consultation
5. Signing the agreement document to join the research program

#### Exclusion criteria:

1. Those with an unstable vital sign
2. Patients who were unable to protrude their tongue or the protruding length was insufficient
3. Those at risk of jaw dislocation
4. Those with an arteriovenous shunt or fistula
5. Those who experience seizures
6. Those with poor cognition and communication

In the control group, we used the previous study and identified 560 participants from September 1, 2014 to December 31, 2016.<sup>32</sup> The participants, with written consent, older than 40 years old, and no specific medical history, namely, acute infection, unstable vital sign, and tongue or oral cancer, were enrolled in the control group. We excluded 273 subjects due to matching the cases based on age younger than 39-year-old, and 1 subject without a clear tongue image. Finally, we enrolled 286 healthy participants and 99 patients with acute ischemic stroke to undergo ATDS analysis (Fig. 1).

### 2.3. Data collection

The collected data included age, sex, diagnosis of stroke, the time between diagnosis of stroke and examination of tongue and pulse diagnosis, NIHSS, Barthel Index aggregate score, past relevant medical history of stroke, like diabetes mellitus (DM), and hypertension (HTN), hyperlipidemia, cardiovascular disease, and atrial fibrillation), image studies (e.g., CT and MRI), and laboratory data (e.g., hemoglobin, platelet, blood sugar, glycosylated Hb, uric acid, triglyceride, total cholesterol, low-density cholesterol, high-density cholesterol levels) and TCM physical examination data were used for tongue and pulse diagnosis.

### 2.4. ATDS and tongue features

The ATDS was developed to capture tongue images and automatically extract features reliably to assist TCM physicians in establishing a diagnosis. The value of ATDS depends on its ability to calibrate brightness and color to compensate for variations in intensity and color temperatures from light sources and imaging hardware. The tongue is automatically segmented to derive relevant tongue features. TCM clinical tongue diagnosis is based on nine primary features as follows: tongue shape, tongue color, fur thickness, fur color, saliva, tongue fissure, ecchymosis, tooth marks, and red spots.<sup>32</sup>

A listing of the tongue features extracted is summarized below:

1. Tongue shape: including small, medium, and enlarged
2. Tongue color: including pale, pink, red, and bluish

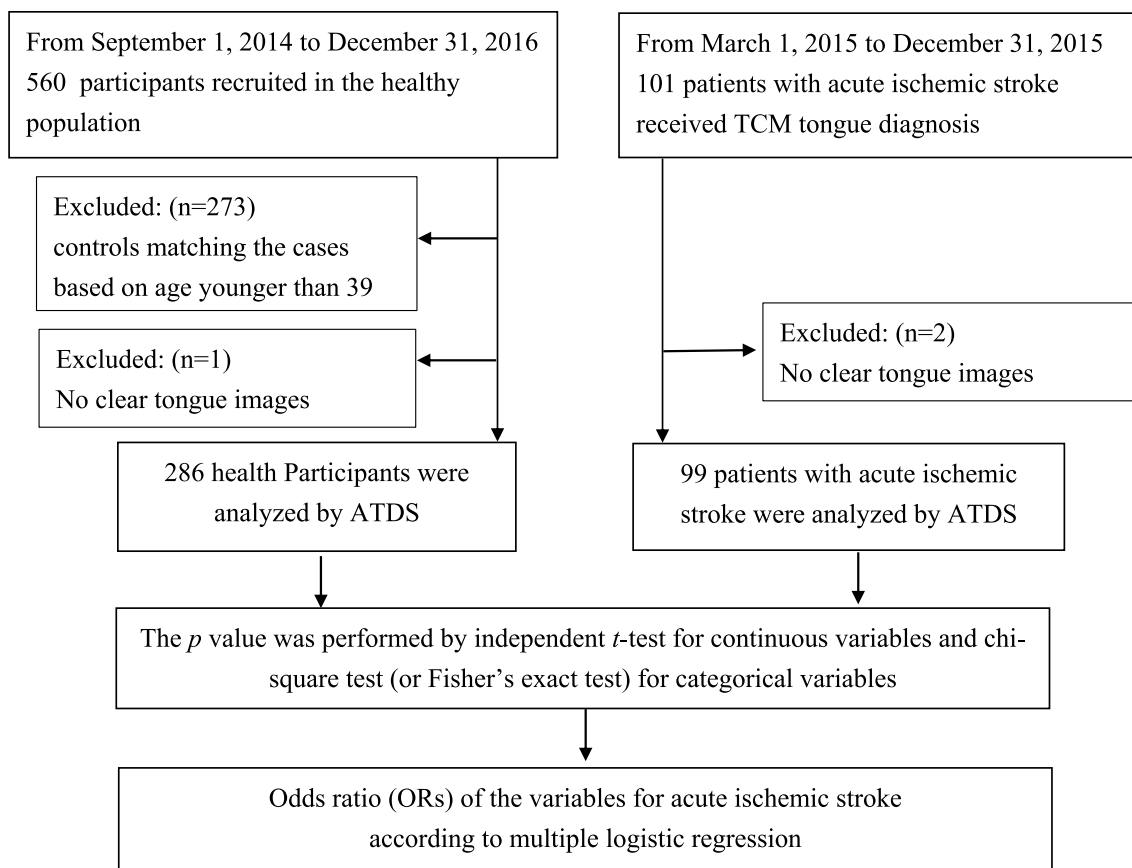


Fig. 1. The exploratory flow chart for acute ischemic stroke-associated tongue diagnosis variates.

3. Fur thickness: degree of thickness (thin or thick), and percentage of thick tongue fur (%)
4. Fur color: including white and yellow
5. Saliva: normal or wet
6. Tongue fissures: amount
7. Tooth marks: amount
8. Ecchymoses: amount
9. Red spots: amount
10. Angle of tongue deviation: the angle between the midline of the tongue and the longitudinal line of the nasal tip to the chin.

### 2.5. Data analysis

The tongue features of the participants were extracted using ATDS, and comparisons were performed between the experimental and control groups to identify features with significant differences ( $p < 0.05$ ). Data are expressed as mean  $\pm$  standard deviation, percentage, or number where appropriate. The tongue features in different groups were analyzed and compared using an independent  $t$ -test for continuous variables and a  $\chi^2$  test (or Fisher's exact test) for categorical variables. Logistic regression was used to estimate the odds ratio and the probability of a binary response based on one or more independent variables. A multiple logistic regression model for acute ischemic stroke was performed by comparing with the participants without stroke. Statistical analysis was performed using SPSS Statistic version 19 (IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY, USA). Statistical significance was set at  $p < 0.05$ .

### 3. Results

The demographic characteristics of the study participants are shown in Table 1. A total of 286 individuals in the control group and 99 patients with acute ischemic stroke were enrolled in the study. The clinical characteristics of the participants were as follows: in the control group, the average age was  $64.2 \pm 8.5$  years and mean body mass index (BMI)  $23.9 \pm 3.3$  kg/m<sup>2</sup>; and in patients with stroke, the average age was  $65.0 \pm 12.5$  years and the mean BMI  $25.0 \pm 3.6$  kg/m<sup>2</sup>. DM and HTN were significantly more common in patients with stroke than in the control group (DM: 11.2% vs. 50.5%,  $p < 0.001$ ; HTN: 91.8% vs. 26.3%,  $p < 0.001$ ). In the ischemic stroke group, the severity of stroke showed the following results: NIHSS ( $4.79 \pm 3.9$ ), Barthel Index ( $64.7 \pm 2.7$ ), and Glasgow Coma Scale (GCS) score ( $14.73 \pm 1.03$ ). Furthermore, to investigate the short-term changes of the tongue features after stroke, the average time from establishing stroke diagnosis to tongue examination was  $3.88 \pm 2.23$  days.

Tongue inspection refers to the examination of prominent tongue features, namely the body shape, tongue color, fur thickness, fur color, and saliva. Differences in the tongue features between the stroke and control groups are shown in Table 2. The proportion of individuals with pale tongue color (6.6% vs. 19.2%) and bluish tongue color (6.3% vs. 15.2%) in the stroke group was significantly higher than that in the control group ( $p < 0.001$ ). The proportion of individuals with fur thickness in the stroke group was significantly greater than that in the control group (31.5% vs. 56.6%,  $p < 0.001$ ). Moreover, the proportion of individuals with yellow fur in the stroke group was significantly greater than that in the control group (28.3% vs. 41.4%,  $p = 0.016$ ). The percentage of thick tongue

fur in the stroke group was significantly greater than that in the control group ( $48.5 \pm 20.1$  vs.  $61.0 \pm 21.0$ ,  $p < 0.001$ ). The number of ecchymoses in the stroke group was significantly greater than that in the control group ( $5.5 \pm 10.6$  vs.  $16.4 \pm 28.7$ ,  $p < 0.001$ ). The angle of tongue deviation ( $2.68 \pm 2.52$  vs.  $4.00 \pm 4.04$ ,  $p = 0.003$ ) was statistically significant in patients with stroke. On the contrary, the number of tooth marks ( $3.5 \pm 2.8$  vs.  $2.0 \pm 2.4$ ) and the number of red spots ( $93.52 \pm 78.38$  vs.  $50.33 \pm 58.13$ ) were significantly less common in patients with stroke than those in the control group ( $p < 0.001$ ).

Logistic regression analysis using utilizing these risk factors and tongue features with significant differences was performed, shown in Table 3. In the multivariable logistic regression analysis, it was found that a history of DM (odds ratio [OR]: 5.179,  $p < 0.001$ ) and HTN (OR: 9.339,  $p < 0.001$ ) in the medical history were statistically significant. Furthermore, while comparing the tongue color, pale tongue color (OR:5.501,  $p < 0.001$ ) and bluish tongue color (OR: 4.249,  $p = 0.014$ ) demonstrated an increased chance of stroke by 5.5 times and 4.2 times, respectively. In contrast, the red tongue color (OR: 0.158,  $p = 0.034$ ) reduced the risk of stroke by 84.2%. In terms of the number of ecchymoses, each ecchymosed spot increased the OR by 5.8% (OR: 1.058,  $p < 0.001$ ). In contrast, each additional tooth marks (OR: 0.765,  $p < 0.001$ ) and red spots (OR: 0.984,  $p < 0.001$ ) reduced the risk of stroke by 23.5% and 1.6%, respectively. As for the tongue deviation (OR: 1.218,  $p < 0.001$ ), an increase in the deviation by  $1^\circ$  increased the OR by 21.8%.

#### 4. Discussion

To the best of our knowledge, this is the first study to apply ATDS to thoroughly investigate the tongue features associated with acute ischemic stroke. In this study, 99 patients with acute ischemic stroke were recruited, and their average NIHSS score, Barthel Index, and average GCS score were  $4.79 \pm 3.9$ ,  $64.7 \pm 27.3$ , and  $14.73 \pm 1.03$ , respectively. These results indicated that these patients were the ones who had mild nerve damage (NIHSS  $< 5$ ), moderate dependency, and clear consciousness. In addition, the time for tongue examination after stroke diagnosis was  $3.88 \pm 2.23$  days, implying that the patients were in acute stages (2–7 days).<sup>30</sup>

Age, sex, obesity, AF, dyslipidemia, HTN, DM, and

**Table 1**  
Demographical features of the study participants.

Variables <sup>a</sup>	Control n = 286	Stroke n = 99	p-value
Age (year)	64.2 ± 8.5	65.0 ± 12.5	0.505
Gender			0.494
Male, N (%)	165 (57.7%)	61 (61.6)	
Female, N (%)	121 (42.3%)	38 (38.4%)	
BMI	23.9 ± 3.3	25.0 ± 3.6	0.009**
Cholesterol (mg/dl)	186.1 ± 33.9	176.4 ± 45.8	0.055
Triglyceride (mg/dl)	113.4 ± 70.6	141.3 ± 90.7	0.006**
Comorbidity			
DM, N (%)	32 (11.2%)	50 (50.5%)	<0.001***
HTN, N (%)	75 (26.3%)	81 (91.8%)	<0.001***
Hyperlipidemia, N (%)	111 (38.9%)	40 (40.4%)	0.798
NIHSS <sup>b</sup>	–	4.79 ± 3.9	
Barthel index <sup>c</sup>	–	64.7 ± 27.3	
GCS score	–	14.73 ± 1.03	
Time from stroke diagnosed to tongue examination (days)	–	3.88 ± 2.23	

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Abbreviation: Body Mass Index, BMI; Diabetes Mellitus, DM; Glasgow Coma Scale, GCS score; Hypertension, HTN; National Institutes of Health Stroke Scale, NIHSS.

<sup>a</sup> All continuous values represented as mean ± standard deviations, and the categorical variables were listed by using the cell number and column percentage between brackets.

<sup>b</sup> National Institutes of Health Stroke Scale (NIHSS) ranges from 0 to 42 scores; the higher the score means higher neuro damage. The NIHSS has a total of 15 items.

<sup>c</sup> Barthel Index is a common life function scale, ranging from 0 to 100 scores. The lower the score, the higher the life-dependency is. Barthel Index has five degrees; scores of 0–20 indicate “total” dependency, 21–60 “severe” dependency, 61–90 “moderate” dependency, 91–99 “slight” dependency, and 100 “total” independence.

**Table 2**  
Comparison of tongue features between patients with stroke and the control group.

Tongue features	Control n = 286	Stroke n = 99	p-value
Tongue shape (n, %) <sup>a</sup>			0.129
Small	43 (15.0%)	10 (10.1%)	
Median	157 (54.9%)	49 (49.5%)	
Enlarged	86 (30.1%)	40 (40.4%)	
Tongue color (n, %) <sup>a</sup>			<0.001***
Pale	19 (6.6%)	19 (19.2%)	
Pink	170 (59.4%)	62 (62.6%)	
Red	79 (27.6%)	3 (3.0%)	
Bluish	18 (6.3%)	15 (15.2%)	
Fur thickness (n, %) <sup>a</sup>			<0.001***
Thin	196 (68.5%)	43 (43.4%)	
Thick	90 (31.5%)	56 (56.6%)	
Fur color (n, %) <sup>a</sup>			0.016*
White	205 (71.7%)	58 (58.6%)	
Yellow	81 (28.3%)	41 (41.4%)	
Saliva (n, %) <sup>a</sup>			0.953
Normal	206 (72.0%)	71 (71.7%)	
Wet	80 (28.0%)	28 (28.3%)	
Thick tongue fur (%) <sup>b</sup>	48.5 ± 20.1	61.0 ± 21.0	<0.001***
Fissures (mean ± SD) <sup>b</sup>	7.3 ± 8.4	7.6 ± 10.0	0.792
Tooth marks (mean ± SD) <sup>b</sup>	3.5 ± 2.8	2.0 ± 2.4	<0.001***
Ecchymoses (mean ± SD) <sup>b</sup>	5.5 ± 10.6	16.4 ± 28.7	<0.001***
Red spots (mean ± SD) <sup>b</sup>	93.52 ± 78.38	50.33 ± 58.13	<0.001***
Tongue deviation angle <sup>b</sup>	2.68 ± 2.52	4.00 ± 4.04	0.003**

p-values performed by chi-square test (or Fisher's exact) for categorical variables or independent t-test for continuous variables.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

<sup>a</sup> Chi-square test (or Fisher's exact).

<sup>b</sup> Independent t-test.

hyperlipidemia are all known risk factors for stroke.<sup>14</sup> In the multivariable logistic regression analysis of the stroke and the control groups, it was observed that among the items with statistical significance, HTN and DM increased the ORs of suffering from stroke by 9.339 times and 5.179 times, respectively. Compared with the study in 2017 that HTN patients with ischemic stroke had a hazard ratio of 5.07 (95% confidence interval = 3.77–6.82)<sup>34</sup> and that patients with type 2 DM had 2-3 times increased of stroke.<sup>35</sup> We supposed that those ORs of this study maybe overestimate,

**Table 3**  
Adjusted odds ratios (ORs) of the tongue features for acute ischemic stroke according to multiple logistic regression analysis.

Variables <sup>a</sup>	Adjusted odds ratio <sup>b</sup>	95% Confidential Interval		p-value
		lower	upper	
Age	1.008	0.972	1.045	0.678
Gender (female)	0.857	0.405	1.813	0.686
DM history	5.179	2.394	11.201	<0.001***
HTN history	9.339	4.361	20.000	<0.001***
BMI	1.000	0.900	1.111	0.998
CHO	0.996	0.987	1.005	0.398
Tongue color				
Pink	1.000			
Pale	5.501	1.953	15.496	0.001***
Red	0.158	0.029	0.867	0.034*
Bluish	4.249	1.337	13.506	0.014*
Fur color (yellow)	1.132	0.516	2.484	0.757
Fur thickness	1.391	0.634	3.050	0.410
Ecchymoses	1.058	1.032	1.084	<0.001***
Tooth marks	0.765	0.664	0.881	<0.001***
Red spots	0.984	0.975	0.993	<0.001***
Tongue deviation angle	1.218	1.085	1.367	0.001**

\*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001.

Abbreviation: Diabetes Mellitus, DM; Hypertension, HTN; Body Mass Index, BMI; Cholesterol, CHO.

<sup>a</sup> The overall variables were assessed association using the logistic regression for acute ischemic stroke and performed by comparing with the patients without stroke.

<sup>b</sup> The represented odds ratios were demonstrated as adjusted odds ratio in the multiple regression analysis model.

because this was case-control study with multiple logistic regression analysis. Moreover, there might be inevitable selection bias, when we selected the participants older than 40 years of age and stroke patients with mild to moderate dependency.

The core of assessment in Chinese medicine is “pattern identification/syndrome differentiation and treatment” based on inspection, hearing and smelling, questioning, and palpation. Through the four methods of diagnosis, TCM physicians can identify diseases and demonstrate body constitution, and then finally decide the treatment strategy. Among the primary diagnostic methods, examination of tongue features plays an indispensable role.

This study aimed to compare the differences in tongue diagnosis between patients with acute ischemic stroke and healthy individuals. Tongue coating represents the retention of exfoliated mucosal cells, debris, and the proliferation of microorganisms, especially on the tongue’s surface of the tongue.<sup>36</sup> Based on TCM theory, the tongue coating is produced by the Wei Qi (spleen-stomach) through fumigation. The stage and prognosis of diseases can be observed and predicted through the tongue coating. Observing changes in the tongue coating to infer systemic disorders involving internal organs as a method of clinical diagnostic method is a unique feature of TCM. The thick fur is usually accompanied by patterns of phlegm dampness and blood stasis.<sup>20,21</sup> In terms of fur thickness, the proportion of thick fur in patients with stroke was significantly higher than that in the control group (56.6% vs. 31.5%, *p* < 0.001). Yellow tongue fur is considered a sign of internal retention of dampness and heat. The proportion of patients with stroke having yellow fur was significantly higher than that in the control group (41.4% vs. 28.3%, *p* = 0.016). While comparing the tongue color, it was observed that pale tongue color and bluish tongue color increased the ORs of stroke by 8.049 times and 5.755 times, respectively. In terms of the tongue features, each ecchymosis increased the incidence of stroke by 1.067 times, whereas tooth marks and red spots lowered the risk of stroke with ORs of 0.755 and 0.981 times, respectively.

In traditional Chinese medicine theory, acute ischemic stroke patients are mostly classified as wind, fire, blood stasis, phlegm syndromes, qi deficiency and blood deficiency.<sup>37,38</sup> The recent study showed among the nine constitution types, qi-deficiency constitution, phlegm-dampness constitution, and blood stasis constitution are the common types, accounting for 25%, 23%, and 17%, respectively, in ischemic stroke patients.<sup>39</sup> The results of this study indicated statistical significance in tongue color bluish, ecchymosis and tongue deviation. The former two belong to blood stasis syndrome, while the latter belongs to wind syndrome. These results supported that TCM recognize that stroke is mainly caused by blood stasis and wind syndrome which was observed from tongue diagnosis thousands of years ago. On the other hand, the three tongue features that manifested negative correlations are tongue color pale, tooth marks and red dots, which belong to blood deficiency, phlegm dampness or qi deficiency, and heat syndrome respectively in tongue diagnosis. Clinically, it is true that blood deficiency and qi deficiency are rare in patients with acute stage, but phlegm dampness and heat syndrome are very common. Those results were inconsistent with clinical experiences, and further researches were needed.

In addition, tongue deviation is mainly observed in patients with stroke. In a previous study, 300 patients with ischemic stroke, 29% of the participants were diagnosed with tongue deviation.<sup>40</sup> The position and configuration of the median raphe about the nasal bridge were used to gauge the deviation. Another study applied the tongue deviation angle to assess the risk of stroke. A tongue deviation angle more than the optimum threshold value (=3.2°) may preliminarily predict the risk of stroke.<sup>41</sup> Therefore, our study based on ATDS was able to effectively evaluate the tongue deviation angle. According to our results, each degree of deviation will increase the OR for ischemic stroke by 1.253 times, such index can be used as a method to evaluate stroke.

However, this study has certain limitations. First, this was a cross sectional hospital-based study. The severity of stroke in this study was mild to moderate and we enrolled patients with acute ischemic stroke who consulted TCM for acupuncture. Therefore, we were not able to fully rule out the possibility of potential selection bias like group differences in patient’s resources, health literacy, and care-seeking behaviors. These results might not be representative of the patients with severe stroke. Second, the baseline characteristics of the two cohorts maybe not be comparable. To resolve this problem, we selected the control group matching to the stroke group for some possible related factors. Third, changes in diet, tooth brushing, and natural tongue conditions may affect the results of the study, and we had excluded participants who eat food or something with a specific color (ex. betel nut) within 1 h to avoid an inaccuracy in tongue examination. However, there might still is an image error we couldn’t avoid. Fourth, we supposed that those ORs of this study may be overestimated, because this was the case-control study with logistic regression. We applied the logistic regression results (Multiple analysis-adjusted) in order to reduce the selection bias rather than propensity score due to less case numbers. Therefore, the cohort study is required to validate these observational findings.

### 5. Conclusion

This study used objective ATDS to explore tongue feature differences among these patients with acute ischemic stroke and healthy controls. The result demonstrated considerably positive correlative statistical significance correlation in tongue features, tongue color pale, bluish tongue, ecchymoses and fur thin. Conversely, tongue color red, tooth marks and red dots indicated opposite correlation with ischemic stroke patients. In conclusion,

the comprehensive results showed that tongue diagnosis can be applied to generate the secondary prevention of stroke, especially in TCM clinical practice.

### Ethics approval

This study was approved by the Institutional Review Board of Changhua Christian Hospital, Taiwan (IRB reference numbers: 150110 and 140704).

### Taxonomy

Identify the disease condition, the experimental approach.

### Funding

The authors would like to thank the China Medical University (CMU109-S-34) for the grant support. This study was supported by program grants from Ministry of Health and Welfare, Taiwan (M09G1047, M1007013), and Ministry of Science and Technology, Taiwan (MOST 110-2314-B-039-023), and China Medical University Hospital, Taiwan (DMR-111-011). The funder will have no role in the trial design, manuscript writing, or decision making for publication.

### Declaration of competing interest

The authors declare that they have no more conflict and financial interests.

### Acknowledgments

The authors were appreciated for the China Medical University Hospital, Taiwan, China Medical University, Taiwan, the Ministry of Health and Welfare, Taiwan, and the Ministry of Science and Technology, Taiwan for the grant support.

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