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# Quantitative Measurement of Dysphonia Severity in Patients With Stroke With Unilateral Vocal Cord Palsy



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## HIGHLIGHTS

- Unilateral vocal cord palsy (UVCP) is frequently observed in patients with stroke.
- Higher UVCP severity possibly had to do with lower dysphonia severity index (DSI).
- The DSI and maximum phonation time (MPT) tests can be helpful in determining the UVCP severity.

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# Quantitative Measurement of Dysphonia Severity in Patients With Stroke With Unilateral Vocal Cord Palsy

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The authors have no potential conflicts of interest to disclose.

## ABSTRACT

Unilateral vocal cord palsy (UVCP) is frequently observed in patients with stroke. This study aimed to evaluate the association between objective dysphonia severity and the classification of UVCP in patients with stroke by objectively and quantitatively measuring their phonetic function. We recruited patients with UVCP diagnosed using laryngoscopy after stroke. Subgroups were divided according to UVCP type, and the dysphonia severity index (DSI) and maximum phonation time (MPT) were measured to objectively evaluate dysphonia. The DSI and MPT were compared between subgroups using analysis of variance with Tukey's honest significant difference post hoc test. In total, 103 patients with stroke and UVCP were recruited. We found that a higher UVCP severity possibly had to do with lower DSI and MPT values. We objectively confirmed that phonetic function was worse in patients with stroke with higher UVCP severity, and the DSI and MPT tests can be helpful in determining the severity and need for additional evaluation.

**Keywords:** Dysphonia; Vocal Cord Palsy; Stroke

## INTRODUCTION

Unilateral vocal cord palsy (UVCP) frequently occurs in patients with stroke. Patients with UVCP experience communication problems due to dysphonia and have a reduced quality of life [1]. UVCP causes shortness of breath, decreased pulmonary function, and difficulty in swallowing [2], resulting in an increased risk of aspiration pneumonia, which can result in mortality [3]. Airway patency and protection require intact vocal cord function [4]. UVCP can be classified using laryngoscopy based on loss of vocal fold adduction and insufficient glottal closure [5]. However, no study has objectively quantified and evaluated dysphonia severity based on these features.

In this study, we performed an acoustic evaluation of patients diagnosed with UVCP and measured the dysphonia severity index (DSI) and maximum phonation time (MPT). We aimed to objectively evaluate dysphonia severity in patients via the DSI and MPT to confirm the relationship between UVCP type and phonetic function. It was expected that this evaluation would help to determine dysphonia severity.

## MATERIALS AND METHODS

### Patients

Patients with stroke admitted to the Department of Rehabilitation Medicine were retrospectively recruited between April 2018 and February 2022. In all patients, UVCP was diagnosed by laryngoscopy, and the DSI and MPT were measured by acoustic evaluation. Other inclusion criteria included a Mini-Mental State Examination (MMSE) score of ≥ 20, capability of cooperating with acoustic arousal assessment, and no other underlying conditions that may cause UVCP, except stroke. All patients had to experience their first stroke onset and had not undergone tracheostomy. The study protocol was approved by the Institutional Review Board (IRB) of Kyung Hee University Hospital at Gangdong, Korea (IRB approval number: 2022-04-012).

### UVCP subgroups

UVCP can be classified according to the position of the paralyzed vocal fold. The vocal fold position was subjectively categorized as paramedian, intermediate, partial abduction, or total abduction [5]. Subgroups were classified according to the precise measurement of the distance between the paralyzed vocal cords and midline. In group A, the vocal fold was in the paramedian position, and the distance from the midline of the unilateral vocal fold was < 1.5 mm; in group B, the vocal fold was in the intermediate position, and the distance from the midline of the unilateral vocal fold was ≤ 3.5 mm. In group C, the vocal fold was at the partial abduction position, and the distance from the midline of the unilateral vocal fold was ≤ 7.0 mm. In group D, the vocal fold was at the position of total abduction, and the midline of the unilateral vocal fold was ≤ 9.5 mm (**Table 1**) [5].

### MPT

During the examination, the patient was asked to sit upright. The test method involved first instructing the patient to inhale as much as possible and then make and maintain the “ah” sound in a normal-speaking voice. The MPT was recorded by measuring the duration of retention [6]. The measurements were repeated 3 times, with a 1-minute rest period between tests, and the maximum time was obtained.

### DSI

The DSI approaches +5 for normal individuals and −5 for those with severe dysphonia. The DSI was calculated by examining each item using a multidimensional speech program involving the metrics minimum intensity, jitter, and highest fundamental frequency, as follows [7]:

$$\text{DSI} = 0.13 \times \text{MPT} + 0.0053 \times \text{The Highest Fundamental Frequency} - 0.26 \times \text{Minimum Intensity} - 1.18 \times \text{Jitter} + 12.4$$

**Table 1.** Unilateral vocal cord palsy

| Group | Vocal fold position | Distance from the midline (mm) |
|---|---|---|
| Group A | Paramedian | 1.5 |
| Group B | Intermediate | 3.5 |
| Group C | Partial abduction | 7.0 |
| Group D | Total abduction | 9.5 |


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### Statistical analysis

SPSS version 25.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. The Kolmogorov-Smirnov test was used to determine data normality. Homogeneity of variances between groups was determined using Levene's test. For continuous data, analysis of variance was combined with Tukey's honest significant difference post hoc test to identify significant differences across subgroups. For categorical data, the $\chi^2$ test was used to compare the prevalence and percentage of classifications. The significance level for all statistical tests was set at $p < 0.05$.

## RESULTS

### Patients

Overall, 103 patients were included in this study, comprising 48 men and 55 women, with a mean age of 68.71 ± 13.37 years. According to stroke type, 53 and 50 patients had ischemic and hemorrhagic strokes, respectively. The mean Modified Barthel Index (MBI) of the patients was 52.25 ± 15.54, and the mean score of the MMSE examination was 23.43 ± 3.30, indicating that the participants had a level of cognitive function and daily living ability that were sufficient to cooperate with the examination. The mean DSI was −1.23 ± 2.15, and the mean MPT was 8.43 ± 2.33, indicating dysphonia (**Table 2**). There were no statistically significant differences in age, sex, stroke type, MBI, or MMSE scores between the subgroups (**Table 3**).

**Table 2.** Patient demographic and clinical data

| Characteristic | Value |
|---|---|
| Age (yr) | 68.71 ± 13.37 |
| Sex | |
| Male | 48 (46.60) |
| Female | 55 (53.40) |
| Stroke type | |
| Ischemic | 62 (60.20) |
| Hemorrhagic | 41 (39.80) |
| Lesion | |
| Supratentorial | 18 (17.48) |
| Infratentorial | 85 (82.82) |
| MBI | 52.25 ± 15.54 |
| MMSE | 23.43 ± 3.30 |
| DSI | −1.23 ± 2.15 |
| MPT | 8.43 ± 2.33 |

Values are presented as the mean ± standard deviation or number (%).
MBI, Modified Barthel Index; MMSE, Mini-Mental State Examination; DSI, dysphonia severity index; MPT, maximum phonation time.

**Table 3.** Comparison of clinical data between subgroups

| Characteristic | Group A (n = 29) | Group B (n = 20) | Group C (n = 31) | Group D (n = 23) | p value |
|---|---|---|---|---|---|
| Age (yr) | 67.62 ± 12.87 | 69.25 ± 13.82 | 69.45 ± 11.28 | 68.65 ± 16.63 | 0.958 |
| Sex | | | | | 0.577 |
| Male | 13 (44.80) | 7 (35.00) | 17 (54.80) | 11 (47.80) | |
| Female | 16 (55.20) | 13 (65.00) | 14 (45.20) | 12 (52.20) | |
| Stroke type | | | | | 0.916 |
| Ischemic | 17 (58.60) | 11 (55.00) | 19 (61.30) | 15 (65.20) | |
| Hemorrhagic | 12 (41.40) | 9 (45.00) | 12 (38.70) | 8 (34.80) | |
| MBI | 51.72 ± 14.80 | 54.00 ± 13.01 | 51.73 ± 13.89 | 52.08 ± 14.45 | 0.957 |
| MMSE | 22.79 ± 2.67 | 23.45 ± 3.88 | 24.64 ± 3.25 | 22.60 ± 3.29 | 0.081 |

Values are presented as the mean ± standard deviation.
MBI, Modified Barthel Index; MMSE, Mini-Mental State Examination.


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**Table 4.** Comparison of the DSI and MPT between subgroups

| Characteristic | Group A (n = 29) | Group B (n = 20) | Group C (n = 31) | Group D (n = 23) | p value | Post hoc p value | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A and B | A and C | A and D | B and C | B and D | C and D |
| DSI | −0.35 ± 1.67 | −0.87 ± 1.93 | −1.75 ± 2.04 | −1.93 ± 2.63 | 0.019* | 0.049* | 0.044* | 0.001* | 0.043 | 0.025* | 0.036* |
| MPT | 11.39 ± 1.39 | 8.90 ± 0.45 | 7.34 ± 0.89 | 5.77 ± 0.83 | 0.011* | 0.042* | 0.039* | < 0.001† | 0.032* | 0.011* | 0.023* |

Values are presented as the mean ± standard deviation.
DSI, dysphonia severity index; MPT, maximum phonation time.
*p < 0.05; †p < 0.00.

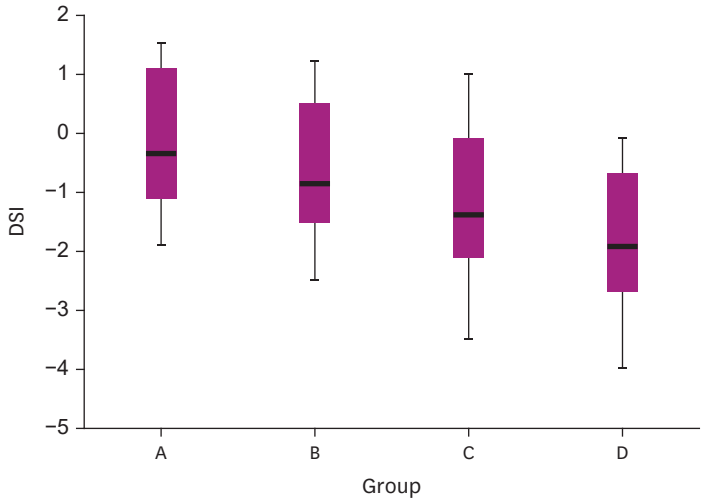


**Fig. 1.** Comparison of the dysphonia severity index in groups A, B, C, and D.
DSI, dysphonia severity index.

### Comparison of phonetic functions between subgroups

Patients were divided into 4 subgroups according to UVCP type, and their phonation functions were compared. The mean DSIs were −0.35 ± 1.67, −0.87 ± 1.93, −1.75 ± 2.04, and −1.93±2.63 in groups A–D, respectively. A significant difference in the DSI was observed between groups A and B (p = 0.049), A and C (p = 0.044), A and D (p = 0.001), B and C (p = 0.043), B and D (p = 0.025), and C and D (p = 0.036) (**Table 4**, **Fig. 1**).

The mean MPTs were 11.39 ± 1.39, 8.90 ± 0.45, 7.34 ± 0.89, and 5.77 ± 0.83 in groups A–D, respectively. Significant differences in the MPT were observed between groups A and B (p = 0.042), A and C (p = 0.039), A and D (p < 0.001), B and C (p = 0.032), B and D (p = 0.011), and C and D (p = 0.023) (**Table 4**, **Fig. 2**).

## DISCUSSION

This study showed statistically significant differences in the DSI and MPT according to UVCP type in patients with stroke. As the unilateral vocal cord became more abducted, the DSI and MPT decreased. Paralyzed vocal cords are defined as vocal cords frozen in an immobile position; the more abducted that position is, the more dysphonia can occur [8].

Dysphonia is a strong indicator of vocal cord dysfunction and a significant clinical characteristic of patients with aspiration [9]. Both apparent and silent aspirations are major complications of stroke [10]. Unilateral vocal cord paralysis interferes with adequate airway protection. This mechanism sometimes prevents aspiration of oral contents into the lungs


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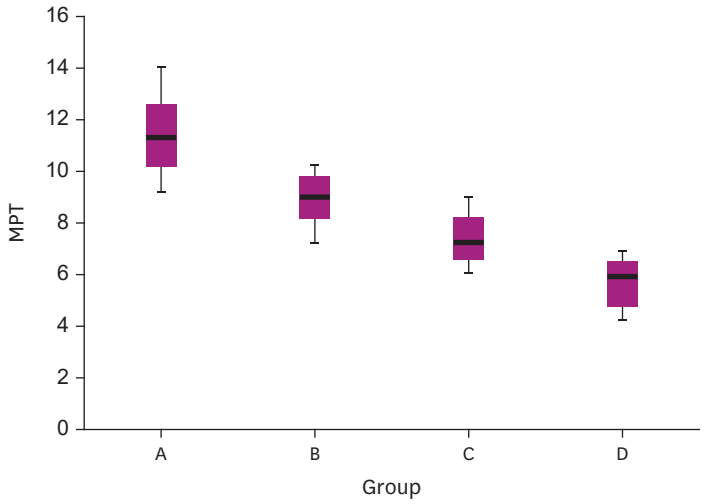


**Fig. 2.** Comparison of the maximum phonation time in groups A, B, C, and D.
MPT, maximum phonation time.

but can also increase the risk of aspiration from refluxed gastric contents. Aspiration can cause life-threatening aspiration pneumonia [4].

The DSI and MPT have been shown to be trustworthy measures of voice assessment because they are well correlated with perceptual and objective multiparametric assessments of dysphonia severity [11,12]. One benefit of DSI and MPT measurements is that they allow speech pathologists to collect parameters quickly and easily in regular clinical practice [13]. These phonetic parameters are associated with dysphagia severity [14]. The MPT can be easily measured without other special speech evaluation tools and has been proven to be a very reliable measure in speech assessment, but it has a disadvantage in that there is variability of results depending on test conditions and participant characteristics [12]. To calculate DSI, it is necessary to measure parameters including the highest fundamental frequency, minimum intensity, and jitter using the Praat program in addition to the MPT. In this study, both MPT and DSI were evaluated to see whether MPT alone could correlate with UVCP severity or whether DSI measurement was required for a more accurate evaluation.

Therefore, in patients with stroke with dysphonia, it is important to not only check for the presence of UVCP by laryngoscopy but also objectively measure dysphonia severity using acoustic parameters to confirm the patient's degree of dysphonia. An objective assessment of dysphonia severity makes it possible to present a treatment plan for the patient, such as the need for speech therapy, determination of the treatment effect, and whether to continue treatment.

A limitation of this study is the small number of participants. Furthermore, we did not consider the fact that paralysis of the unilateral vocal cord on the affected side is sometimes compensated by the movement of the vocal cord on the opposite side to compensate for phonetic function [15]. A randomized prospective study with more patients that considers compensation according to the movement of the normal vocal cords is needed to validate our findings.

In conclusion, the higher the severity of UVCP in patients with stroke, the higher the dysphonia severity. These results seem to be able to provide objective evidence for the effect of vocal cord position on phonetic function.


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