Clinical Characteristics of Swallowing Disorders Caused by Cerebrovascular Disease: A Study Using Newly-developed Indices for the Basic Elements of Swallowing Movement and Neck Range of Motion

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Abstract. The objective of this study was to elucidate the characteristics of swallowing disorder in cerebrovascular disease (CVD) patients in terms of newly developed indices for the basic elements of swallowing movement and muscle tone in the neck. A total of 133 patients participated in our study, 116 patients with CVD and 17 elderly patients who had no history of dysphagia and CVD. These patients were divided into 5 groups according to the existence of swallowing disorder and interval from onset. The effects of CVD and swallowing disorder were elucidated by two-group comparison. Measurement items consisted of and passive neck ROM in 4 directions (flexion, extension, lateral flexion, and rotation.) 5 newly developed indices: distance from the genion to the upper end of thyroid cartilage (GT), distance from the upper end of thyroid cartilage to the upper end of sternum (TS), length of the suprahyoid and infrahyoid muscles on neck extension (GT+TS), relative larynx position (GT/(GT+TS)), and strength of the suprahyoid muscles (GS grade). Patients with CVD of less than 90 days’ duration exhibited GT shortening, decline in GS grade, and limitations in neck extension and rotation ROM. In the chronic phase, TS shortening, laryngeal lowering, and limitations in neck flexion and lateral flexion ROM were observed. Physical therapists should aim to improve the factors that might impede laryngeal movement and to conduct preparatory exercises that facilitate swallowing movements.

Key words: stroke, dysphagia, swallowing movement

Nearly half of patients with cerebrovascular disease (CVD) are considered to have dysphagia1-4). Respiratory physical therapy is performed for swallowing disorder, as which is considered to negatively impact early rehabilitation in the acute phase and can even be life threatening. On the other hand, as for interventions for dysphagia itself, only a few reports of systemic approaches such as postural maneuvers or local approaches to muscles involved in swallowing have been published5-6).

Laryngeal movement in swallowing is generated by the upward and forward movement of the hyoid bone caused by contraction of the suprathyroid muscles and by elevation of the thyroid cartilage by the thyrohyoid muscle. It plays a central role in the swallowing reflex, ensuring epiglottic closure and the sequential movements needed to open the esophageal entrance. Laryngeal descent with advancing age, leading to insufficient upward and forward laryngeal movement, is considered to impede opening of the esophageal entrance even in healthy subjects. In this regard, Shaker has reported the efficacy of head raising exercises as a strengthening method for the suprathyroid muscles7).

Besides bulbar palsy due to lesions of the deglutition center and pseudobulbar palsy due to bilateral cerebral dysfunction, there are several other causes of dysphagia, including consciousness disorder, sensory disturbance, and

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higher neurological disorder including disturbance of attention. Furthermore, even unilateral cerebral disorder is reported to cause dysphagia8,9. Dysphagia seems to result not only from the effect of a transient decrease in contralateral cerebral blood flow, but also from the effect of postural tone as an internal factor interfering with swallowing movement.

The objective of this study was to compare three groups (elderly group, CVD without dysphagia group, and CVD with dysphagia group) using indices developed to measure relative larynx position and the function of the suprahyoid muscles in addition to neck range of motion (ROM), which is believed to reflect muscle tone around the neck, in order to clarify the clinical characteristics of swallowing disorder caused by CVD and the relations between neck-trunk function and motor dysphagia.

Methods

Subjects (Table 1)

A total of 133 subjects were enrolled in our study, 17 elderly patients who had ambulatory ability but no history of CVD and dysphagia, and 116 elderly patients suffering from CVD. Subjects were divided into 5 groups according to the existence of swallowing disorder and interval from onset of CVD symptoms: group A (control group), 17 elderly patients who were hospitalized at M hospital with orthopedic disorders with the exception of spinal disease, had no internal disease and were ambulant (mean age 77.6 ± 8.7); group B (early stage CVD without dysphagia group), 18 patients without dysphagia who had developed CVD less than 90 days previously (mean age 73.6 ± 11.2); group C (chronic CVD without dysphagia group), 20 patients without dysphagia who had developed CVD more than 90 days previously during hospitalization (mean age 74.6 ± 7.7); group D (early stage CVD with dysphagia), 46 patients who had developed CVD less than 90 days previously and had residual dysphagia of at least 1 month in duration (mean age 71.6 ± 13.2); and group E (chronic phase CVD with dysphagia), 32 patients who had developed CVD more than 90 days previously during hospitalization, and exhibited residual swallowing disorder of at least 1 month in duration (mean age 82.8 ± 7.25). In order to exclude transient syndromes and distinguish the recovery-stage, we employed durations of at least one month after onset and less or more than 90 days after onset.

Criteria for diagnosis of swallowing disorder were motor functional disorders of the tongue, larynx, and soft palate etc., and clinical condition of dysphagia according to Saitoh’s classification (Table 2)10,11. Patients presenting with dysphagia mainly caused by consciousness disturbance, higher neurological disorder, or sensory disturbance were excluded from the current study.

Consequence assessment

Nine measurement items were selected: distance from genion to the top of the thyroid cartilage with neck extension (GT), distance from the top of the thyroid

Table 1. Baseline characteristics of the subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>M / F (number)</th>
<th>Average age (years)</th>
<th>CVD</th>
<th>From onset (days)</th>
<th>motor dysphagia</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>17</td>
<td>7 / 10</td>
<td>77.6 ± 8.7</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>B</td>
<td>18</td>
<td>8 / 10</td>
<td>73.6 ± 11.2</td>
<td>〇</td>
<td>38.7 ± 20.0 (32)</td>
<td>–</td>
</tr>
<tr>
<td>C</td>
<td>20</td>
<td>12 / 8</td>
<td>74.6 ± 7.7</td>
<td>〇</td>
<td>1412.4 ± 1435.4 (862)</td>
<td>–</td>
</tr>
<tr>
<td>D</td>
<td>46</td>
<td>28 / 18</td>
<td>71.6 ± 13.2</td>
<td>〇</td>
<td>41.1 ± 16.7 (33)</td>
<td>〇</td>
</tr>
<tr>
<td>E</td>
<td>32</td>
<td>7 / 25</td>
<td>82.8 ± 7.3</td>
<td>〇</td>
<td>1469 ± 1084.7 (1172)</td>
<td>〇</td>
</tr>
</tbody>
</table>

Groups B and D (Early stage): less than 90 days from onset.
Groups C and E (Chronic stage): more than 90 days from onset.
From onset: mean days ± standard deviation (medium value).

Table 2. Saitoh’s classification of dysphagia (translation into English and partial change by authors)

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Normal</td>
</tr>
<tr>
<td>6</td>
<td>Minimal problems</td>
</tr>
<tr>
<td></td>
<td>No aspiration, only small dietary changes required</td>
</tr>
<tr>
<td>5</td>
<td>Oral problems</td>
</tr>
<tr>
<td></td>
<td>No aspiration, difficulties in the oral stage</td>
</tr>
<tr>
<td>4</td>
<td>Chance aspirator</td>
</tr>
<tr>
<td></td>
<td>Aspiration occurs with improper positioning or large bolus</td>
</tr>
<tr>
<td>3</td>
<td>Water aspirator</td>
</tr>
<tr>
<td></td>
<td>Dietary change is effective</td>
</tr>
<tr>
<td>2</td>
<td>Food aspirator</td>
</tr>
<tr>
<td></td>
<td>Dietary change is not adequate, tube feeding level</td>
</tr>
<tr>
<td>1</td>
<td>Saliva aspirator</td>
</tr>
<tr>
<td></td>
<td>High risk of pneumonia by saliva aspiration</td>
</tr>
</tbody>
</table>
cartilage to the sternal notch with neck extension (TS),
length of the extended suprahyoid and subhyoid muscles
(GT+TS), relative larynx position (T-position; GT / (GT+TS)), strength of the suprahyoid muscles (GS grade),
and passive neck ROM in four directions (flexion,
extension, lateral flexion, and rotation). The first five
indices were developed for assessing the factors that
impede laryngeal movement in swallowing (Figs. 1, 2) 12). We added to them passive neck ROM which reflects muscle
tone around the neck.

GT indicates the degree of shortening in the suprahyoid
muscles and TS reflects the degree of shortening in the
subhyoid muscles. GT and TS were measured with a tape
measure with the neck fully extended and with the patient in
the side-lying position.

To measure GS grade, the patient was placed in the
supine position with the neck passively and fully flexed and
was directed to maintain this position with the chin down.
Support was then withdrawn and the level to which the head
dropped was evaluated in four steps.

Relative larynx position reflects the tensile balance of
the suprahyoid and subhyoid muscles and is an index
representing the thyroid level relative to the genion and
sternum. This was calculated using the formula GT /
(GT+TS), based on measured GT and TS.

Passive neck ROM was measured in a supine position,
using a self-made measuring board, according to
procedures defined by the Japanese Orthopedic Association
and Japanese Association of Rehabilitation Medicine in
1995. As for lateral flexion and rotation in passive neck
ROM, to reflect asymmetrical posture due to hemiplegia,
ROM was measured on both sides and the lowest value was
used. Reliability within and between the examinations
involved in measurements of the above indices was verified
prior to the examinations, and high reliability was
confirmed.

Analysis

A two-group comparison was performed to elucidate
the clinical characteristics of swallowing disorder based on
the effect of CVD alone at each interval from onset examined in our study.

To determine the effect of CVD alone, groups A and B
were compared for the early phase, whereas groups A and C
were compared for the chronic phase. To determine the
effect of CVD and swallowing disorder, groups A and D
were compared for the early stage, whereas groups A and E
were compared for the chronic stage. To determine the
effect of swallowing disorder alone, groups B and D were
compared for the early phase, whereas groups C and E were
compared for the chronic phase. To determine
characteristics of swallowing disorder at different intervals
from onset, groups D and E were compared. The Mann-
Whitney U-test was used for statistical analysis. The
significance level was defined as less than 5%.

Results (Table 3, 4)

Shortened GT, limitation in neck flexion in the early
phase, and limitation in neck ROM except for rotation in the
chronic phase were identified as isolated effects of CVD.

Concerning the effects of CVD and swallowing
disorder, in the early phase, shortened GT, TS, and GT+TS,
decline in GS grade, and limitations in neck extension and
rotation were apparent. In the chronic phase, shortened
GT+TS, lowered T-position caused by TS shortening,
decline in GS grade, and limitations in neck flexion and
lateral flexion were also revealed.

Swallowing disorder alone was found to result in
significant differences in GS grade and neck rotation in the
early phase, and significantly shortened TS, lowered T-
position, and diminished GS grade and neck lateral flexion
in the chronic phase.

Regarding interval from onset, swallowing disorder
was characterized by shortened GT in the early phase, and
by a decline in T-position caused by TS shortening, and
limitations in neck flexion and lateral flexion in the chronic
phase.
**Table 3.** Average of newly-developed indices and neck range of motion in each group

<table>
<thead>
<tr>
<th>Group</th>
<th>GT(cm)</th>
<th>TS(cm)</th>
<th>GT+TS(cm)</th>
<th>T-position</th>
<th>GS grade</th>
<th>Flexion</th>
<th>Extension</th>
<th>Rotation</th>
<th>Lateral Flex.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (N=17)</td>
<td>6.6 ± 1.0</td>
<td>9.5 ± 1.1</td>
<td>16.1 ± 1.1</td>
<td>0.41 ± 0.05</td>
<td>4.0 ± 0.0</td>
<td>44.1 ± 9.9</td>
<td>51.2 ± 11.3</td>
<td>55.0 ± 11.3</td>
<td>35.0 ± 12.6</td>
</tr>
<tr>
<td>B (N=18)</td>
<td>5.5 ± 1.2</td>
<td>8.9 ± 1.8</td>
<td>14.4 ± 2.8</td>
<td>0.38 ± 0.03</td>
<td>3.8 ± 0.5</td>
<td>35.8 ± 9.6</td>
<td>44.4 ± 11.9</td>
<td>58.9 ± 14.0</td>
<td>30.0 ± 12.1</td>
</tr>
<tr>
<td>C (N=20)</td>
<td>6.7 ± 0.8</td>
<td>9.1 ± 1.2</td>
<td>15.8 ± 1.1</td>
<td>0.43 ± 0.04</td>
<td>3.8 ± 0.6</td>
<td>34.3 ± 7.7</td>
<td>43.5 ± 7.6</td>
<td>51.3 ± 7.4</td>
<td>27.5 ± 7.5</td>
</tr>
<tr>
<td>D (N=46)</td>
<td>5.4 ± 1.2</td>
<td>8.3 ± 1.5</td>
<td>13.7 ± 2.2</td>
<td>0.39 ± 0.05</td>
<td>2.8 ± 1.2</td>
<td>38.6 ± 14.7</td>
<td>40.9 ± 11.1</td>
<td>44.8 ± 15.6</td>
<td>28.3 ± 10.9</td>
</tr>
<tr>
<td>E (N=32)</td>
<td>6.4 ± 1.0</td>
<td>7.6 ± 1.2</td>
<td>14.1 ± 1.8</td>
<td>0.46 ± 0.05</td>
<td>3.0 ± 1.2</td>
<td>29.2 ± 12.0</td>
<td>39.4 ± 10.0</td>
<td>44.8 ± 11.1</td>
<td>19.5 ± 8.1</td>
</tr>
</tbody>
</table>

**Table 4.** Two group comparisons to determine the effect of CVD, motor dysphagia, different intervals from onset

<table>
<thead>
<tr>
<th>Newly-developed indices of swallowing movement</th>
<th>Neck Range of motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT</td>
<td>TS</td>
</tr>
<tr>
<td>A-B CVD or not (Early)</td>
<td>*</td>
</tr>
<tr>
<td>A-C CVD or not (Chronic)</td>
<td>–</td>
</tr>
<tr>
<td>A-D Early stage motor dysphagia</td>
<td>***</td>
</tr>
<tr>
<td>A-E Chronic motor dysphagia</td>
<td>–</td>
</tr>
<tr>
<td>B-D Motor dysphagia or not (Early)</td>
<td>–</td>
</tr>
<tr>
<td>C-E Motor dysphagia or not (Chronic)</td>
<td>–</td>
</tr>
<tr>
<td>D-E Different intervals from onset</td>
<td>***</td>
</tr>
</tbody>
</table>

*Mann-Whitney U-test. *: p<0.05, **: p<0.01, ***: p<0.001.

**Discussion**

Why did GT shortening occur in the early phase CVD group?

Most patients with CVD of less than 90 days duration tend to lie supine all day. GT shortening was therefore considered to be attributed to this posture rather than the existence of paralysis in the swallowing muscles. In their usual posture, a kinetic chain might develop predominantly from around the occipital area, returning the thyroid to the genion by reverse action of the suprahyoid muscles. In this situation, the thyroid might be prone to upward displacement.

Why did limitation in neck ROM and TS shortening cause lowering of the larynx in chronic phase CVD?

Patients with chronic phase CVD generally sit in a wheelchair during the day. The strength required to maintain neck and trunk position is limited by motor paralysis and these patients also tend to exhibit asymmetric posture due to hemiplegia. Muscle tension around the neck and in the infrahyoid muscles is accordingly heightened to maintain the position of the head and, due to limitation in neck ROM and TS shortening, lowering of the larynx occurs. In addition, for these reasons, limitation in neck ROM in the acute and chronic phases might occur in different directions.

The clinical usefulness of GS grade

The findings of each two-group comparison demonstrated that GS grade reflects swallowing disorder independently of the existence of CVD. Therefore, to ensure laryngeal movement in swallowing, it is necessary to facilitate maintenance of the elevated head position with the chin down. Shaker et al. reported interventional effects using a set of exercises (three times a day, for 6 weeks): 30 repetitions of head elevation, and three repetitions maintaining the head in an elevated position for 1 min7). Although this maneuver seems to be effective in healthy subjects, it can be very difficult for patients with CVD to perform. It is also unclear whether the maneuver selectively strengthens the suprahyoid muscles. However, by applying support and resistance, physical therapists can effectively perform kinesitherapy in which the burden on the patient is considerably reduced. The GS grade was considered to be clinically useful as an index for selecting patients who are suitable candidates for treatment of dysphagia, and for confirmation of the effects of treatment12).
Significance of relative larynx position and neck ROM

The relative larynx position is representative of the starting position of laryngeal movement. Even if laryngeal upward movement occurs in the displaced upper position, appropriate epiglottic closure and sequential opening at the site of the esophageal entrance cannot be ensured. Since it takes a long time to conduct upward laryngeal movement from the lowered position, descent of the food bolus may be delayed. The position of the larynx in swallowing depends on the balance of tension between the suprahyoid and subhyoid muscles. So, this position could be a key element of laryngeal movement. Based on characteristics in the early and chronic phase, correcting laryngeal position could be one of the elements facilitating swallowing movement.

Passive neck ROM is considered to reflect muscle tone around the neck, which could interfere with laryngeal elevation. Minimizing the degree and asymmetry of ROM might therefore be good preparation for facilitating swallowing movement. However, these characteristics might result from adaptive activities to each posture based on the function in the neck and trunk and the ability to maintain this posture. Hence, it appears important to focus not only on the affected region, but also to consider the underlying cause.

Conclusion

In this study we used newly developed indices for the basic elements of swallowing movement, which evaluate factors that might impede laryngeal movement in swallowing, and neck ROM. With these indices, characteristics of swallowing disorder could be elucidated among patients with early (less than 90 days from the onset) and chronic CVD. In the treatment of CVD patients with swallowing disorder, we consider the indices of laryngeal movement to be clinically significant for a notable motion element and for quantitative evaluation of treatment effect. Physical therapists should evaluate patients with these indices, and treat them based on the results with programs intended to facilitate swallowing movements.

References