In this study, bolus passage through the pharynx and the mechanism that causes laterality of bolus passage were examined in 29 dysphagic patients with Wallenberg’s syndrome (63±10 years). Video-fluorography was taken to visualize the bolus passage. For the purposes of analysis, the pharynx was divided into the thyropharyngeal portion and the cricopharyngeal portion. The period after disease onset of the cases with bolus passage dominantly on the affected side in the thyropharyngeal portion was significantly shorter than that of cases with bolus passage on both sides. The period was not different among the passage sides in the cricopharyngeal portion significantly. The bolus passages in the cricopharyngeal portion were significantly associated with the passages in the thyropharyngeal portion. Passage of the bolus dominantly on the affected side in the thyropharyngeal portion may be attributed to the asymmetric contraction of the pharynx caused by the paralysis of the pharyngeal constrictor. Together, the bolus passage in the thyropharyngeal portion and the open status of the cricopharyngeal portion presumably determine the path that the bolus takes in the cricopharyngeal portion.

Key words: Wallenberg’s syndrome, dysphagia, videofluorography, bolus passage, cricopharyngeal muscle

Introduction

Wallenberg’s syndrome (also called lateral medullary syndrome) is caused by a stroke in the vertebral or posterior inferior cerebellar artery of the brainstem. Symptoms include difficulties with swallowing, hoarseness, diminished gag reflex, vertigo, diplopia, nystagmus, vomiting, ipsilateral Horner’s syndrome, ipsilateral loss of pain and temperature sensation from face and contralateral deficits in pain and temperature sensation from body.

The focus responsible for Wallenberg’s syndrome lies in a lateral medulla. The difficulty of swallowing is thought to occur when premotor neurons in the nucleus ambiguus or the nucleus tractus solitarius and its surrounding reticular formation, which acts as a central pattern generator (CPG), are affected. The symptoms vary according to the sites that are actually affected, unilateral or bilateral pharyngeal dysfunction and bolus passage laterality at the cricopharyngeal portion often occur.

Based on swallowing studies in healthy adults using videofluorography (VF), the bolus passes by both sides of the pyriform sinuses and the cricopharyngeal portion. However, in patients with dysphagia due to Wallenberg’s syndrome, laterality of bolus passage at the cricopharyngeal portion is often observed.
Since cricopharyngeal dysfunction is more frequently observed on the affected side than on the non-affected side, it is generally assumed that boluses pass through the non-affected side more easily. Thus, during direct exercise or oral intake of food, Wallenberg’s syndrome patients who have dysphagia are often instructed to rotate the neck to the affected side as a compensatory method; this is an effective maneuver for directing the boluses towards the side opposite to the rotation\textsuperscript{7-10}.

On the other hand, it has also been reported that, in some cases, the dominant bolus passage side can be the affected side of the cricopharyngeal portion. Furthermore, the dominant bolus passage side has been found to change over time\textsuperscript{5,6}. Thus, the details concerning the bolus passage side remain controversial.

Therefore, the purpose of the present study was to investigate bolus passages through the pharynx over time and the mechanism causing laterality in patients with Wallenberg’s syndrome. We also examined the relation between bolus passages and severities of dysphagia.

Materials and Methods

Subjects

Twenty-nine patients with Wallenberg’s syndrome who visited the Department of Rehabilitation Medicine, School of Medicine, Fujita Health University and who underwent VF from March 1999 to November 2005 were studied. There were 24 males and 5 females; their age ranged from 35 to 78 years, and their average age was $63 \pm 10$ years. The etiology of Wallenberg’s syndrome included 26 cases of medullary infarction and 3 cases of medullary infarction following subarachnoid hemorrhage.

The diagnosis of Wallenberg’s syndrome was based on the identification of an infarcted focus on head MRI along with the following characteristic clinical symptoms: thermalgic paralysis of the face, trunk, and extremities; Horner’s syndrome; and paralyses of the soft palate, the pharyngeal constrictor, and the vocal cords. Cases with bilateral foci on MRI were excluded.

Informed consent about VF examination had been obtained from each patient before they underwent the examinations.

Procedure

1. Determination of the affected and non-affected sides

Based on the physical examination, videoendoscopic findings (including the dysfunction of the soft palate, the tongue, the pharyngeal constrictor, and the arytenoid), and the head MRI findings, the affected side and the non-affected side were determined for each case.

2. VF assessment

29 subjects underwent 197 VF examinations. At 149 examinations (average: 5.1 times, range: 3-7 times) bolus passages in the pharynx and effects of head rotation were examined by posterior-anterior views. We gathered their date and evaluated them retrospectively.

2 ml or 4 ml of 50% liquid barium adjusted to a honey-like viscosity using a thickening agent was used when the bolus passages were examined.

To allow the laterality of bolus passage at the pharynx to be studied in detail, the pharynx was divided into two regions: the thyropharyngeal portion (TP), from the vallecula to the pyriform sinus; and the cricopharyngeal portion (CP), from the pyriform sinus to the esophagus (Fig. 1). The laterality of bolus passage was investigated and classified into the following 4 patterns: dominantly on the non-affected side, on both sides (no clear difference between the right and left sides), dominantly on the affected side, and non-passage of the bolus.

Next, we evaluated bolus passage state in 3 grades when they swallowed with their neck rotated to the right and left side: good, slightly bad, and bad. Passage was considered to be “good” when most of the bolus could pass through the CP with no residue left after swallow-

Fig. 1. Evaluated sites for bolus passing side
The thyropharyngeal portion covers from vallecula to pyriform sinus and the cricopharyngeal portion covers from pyriform sinus to esophagus.
ing at the pyriform sinus; passage was considered to be bad when there was no passage through the CP; and passage was considered to be slightly bad when passage was intermediate between the good and bad grades. In addition, the grade was compared with left and right rotation to determine which side was better for swallowing.

The degree of severity based on the clinical severity scale\(^\text{11}\) (Table 1) was evaluated at the first and final evaluations.

### Statistical analysis

Kruskal-Wallis test and Steel-Dwass test for multiple comparisons were used to compare the period after onset of the four passage sides and the severity of the four passage sides at the first and final evaluations. Fisher’s exact probability test was used to examine the association between the passages in the TP and the CP. Wilcoxon’s test was used to compare the severity between the first and final evaluations. A significant difference was accepted at \(p < 0.05\) for all tests.

### Results

#### 1. The affected side of the pharynx and the period after disease onset

The clinical findings of all subjects coincided well with their head MRI findings and the side of the pharynx that was affected. In 13 cases, the left side was affected, and in 16 cases, the right side was affected. The median duration after disease onset was 51 days (8-382 days) at the first evaluation and 376 days (65-2312 days) at the final evaluation. The median period from the first to the final evaluation was 251 days (42-2279 days).

#### 2. Changes in the proportion of bolus passage side over time

To examine changes over time, the 149 evaluations were handled separately and stratified into 5 groups based on time from disease onset: 30 days or less; 31-90 days; 91-180 days; 181-365 days; and 366 days or more (Fig. 2). Bolus passage in the TP was dominantly on the affected side in 8 of the 11 cases (73%) whose time from disease onset was 30 days or less; the percentage decreased to 5% (2 of 42 cases) when the time from disease onset was 366 days or more. On the other hand, bolus passage on both sides was observed in 2 of 11 cases (18%) whose time from disease onset was 30 days or less, the percentage increased to 79% (33 of 42 cases) when the time from disease was 366 days or more. At the first evaluation the period after onset of cases with bolus passage dominantly on the affected side in the TP was significantly shorter than that of cases with bolus passage on both sides (Fig. 3 Steel-Dwass test \(p < 0.05\)).

In the CP, there were 4 cases (36%) each of bolus passage dominantly on the affected side and of non-bolus passage when the time from disease onset was 30 days or less, the percentage increased to 79% (33 of 42 cases) when the time from disease was 366 days or more. At the first evaluation the time from disease onset was 30 days or less, the percentage for these two were higher than for bolus passage on the non-affected side and on both sides. When the time from disease onset was 31 days or more, the percentage of cases with bolus passage dominantly on the non-affected side and with passage on both sides was higher. The period after disease onset was not different among the four passage sides in the CP significantly concerning the first evaluation (Fig. 3 Kruskal-Wallis test).

Changes in the side of bolus passage from the first to the final evaluation in 29 cases are shown in Table 2. At the time of the final evaluation, bolus passage was dominantly on the non-affected side in 13 cases and on both sides in 10 cases. In 19 cases bolus passage was changed from the first to the final evaluation.

#### 3. Relation between the passages in the TP and CP (Table 3)

At the first evaluation the bolus passages on both sides and dominantly on the affected side in the CP were significantly associated with the passages in the TP (Fisher’s exact probability test \(p < 0.05\)).
4. Cases with bolus passage on the affected side in the CP

In 8 cases in whom bolus passage was dominantly on the affected side in the CP at least once, the time from disease onset at the evaluation, the head rotation side that was effective for swallowing and the type of passage in the CP with the head rotated to the affected side and to the non-affected side were studied, as shown in Table 4.

In Cases 1 and 2, head rotation to the non-affected side was more effective; no bolus passage was seen with rotation to the affected side. On the other hand, head rotation to the affected side was more effective with good bolus passage in Cases 3 - 7. In Case 8, there was no difference in bolus passage with head rotation.

5. Severity

5-1 Changes in severity over time (Fig. 4-1)

The overall severity was significantly improved with time after intervention (Wilcoxon's test p < 0.05).

The severity score in patients whose score was 1 (saliva aspiration) at the time of the first evaluation improved to a score of from 2 (food aspiration) to 4 (chance aspiration). In 19 cases who had a severity score of 2 at the time of the first evaluation, the score at the final evaluation was unchanged in 6 cases; in 13 remaining cases, the score improved to from 3 (water aspiration) to 7 (within normal). In the 4 cases that had an initial severity score of 3, the score improved to 4 in
3 cases and 7 in 1 case. Two cases with a severity score of 4 at the time of the first evaluation had no change at the time of the final evaluation. In none of the cases was worsening of the severity score noted over time.

Fig. 3. Period after onset of disease in relation to the passing side
Concerning 29 of the first evaluation the period after onset of cases with bolus passage dominantly on the affected side in the TP was significantly shorter than that of cases with bolus passage on both sides (Steel-Dwass test p<0.05).

Table 2. Changes in the passing side in the CP
Altered passing sides from the first to final evaluation are shown for all 29 cases examined.

| Passing side in the CP | 3 cases | 7 in 1 case | Two cases with a severity score of 4 at the time of the first evaluation had no change at the time of the final evaluation. In none of the cases was worsening of the severity score noted over time.

Table 3. Relation between the passages in the TP and CP at the first evaluation
The bolus passages on both sides and dominantly on the affected side in the CP were significantly associated with the passages in the TP (Fisher's exact probability test p<0.05).

Table 4. Affected side dominantly passing cases in the CP
In 8 cases evaluated to have the affected side dominantly passing in the CP, in Case Nos. 1 and 2, the head rotation to the non-affected side was more effective, while the head rotation to the affected side was contrarily effective in Case Nos. 3-7. In Case No. 8, no right and left difference was observed in the passing state at rotation.

5-2 Severity by bolus passage side (Fig. 4-2)
In the TP, there were no significant differences in the severity among the different bolus passage types (Kruskal-Wallis test). In the CP, the severity was rather high for all bolus passage types at the time of the first evaluation. However, at the time of the final evaluation, the severity was low in cases of bolus passage
dominantly on the non-affected side and in cases with bolus passage on both sides. There were significant differences observed at the time of the final evaluation between the cases with non-bolus passage and those of the bolus passage on both sides or dominantly on the non-affected side, and between the cases of the bolus passage dominantly on the affected side and those of the bolus passage on both sides or dominantly on the non-affected side (Steel-Dwass test \( p < 0.05 \)).

Fig. 4-1. Overall changes in the severity
The overall severity was improved with times with a significant difference between the first and final evaluation (Wilcoxon’s test \( p < 0.05 \)). In those patients who had the severity score of 1 point at first evaluation, the score was improved to 2-4 points at final evaluation. In those with 2 points at first evaluation, the score at final evaluation unchanged in 6 cases but improved to 3-7 points in 13 cases.

Fig. 4-2. Severity by different passing sides
In the CP, There were significant differences observed at the final evaluation between the cases of the non-bolus passage and those of the bolus passage on both sides or dominantly on the non-affected side, and between the cases of the bolus passage dominantly on the affected side and those of the bolus passage on both sides or dominantly on the non-affected side (Steel-Dwass test \( p < 0.05 \)).

Discussion

Among patients with impairment of the brainstem, dysphagia is seen in 50-90% but in most cases improves rapidly and 80-90% patients can start oral feeding in 1 to 4 months\textsuperscript{12-17}. However in some cases dysphagia lasts for many months or years. To treat Wallenberg’s syndrome patients and other bulbar palsy with dysphagia, it is important to understand the pathological kinesis of the swallowing state. After evaluation of bolus passage, particularly in the CP, an appropriate training approach or positional alteration during mealtimes can be determined.

Logemann et al. investigated the laterality of bolus
passage at the CP in healthy individuals\textsuperscript{7}. According to their study, in 2 of 6 cases, the boluses passed on the left side, and in 4 cases the boluses passed through on both sides. When the subjects rotated their neck to one side, the boluses were directed to the opposite side and went through the pyriform sinus. Konya et al. reported that, of 30 healthy individuals, the bolus passed dominantly on the right side of the CP in 1 case, dominantly on the left side in 3 cases, and on both sides in 26 cases\textsuperscript{18}. Ohta et al. studied one healthy subject and found that boluses passed through the CP on both sides\textsuperscript{5}. When the subject rotated his head to one side, the boluses were directed to the opposite side. Given these data from normal subjects, once swallowed, a bolus is likely to pass through both sides of the CP; with the head rotated to one side, the bolus passes through the opposite side\textsuperscript{7,8,18}.

In contrast to the findings in normal subjects, Fujishima et al. found that, in 29 Wallenberg's syndrome patients with dysphagia in the acute phase\textsuperscript{5}, bolus passage occurred dominantly on the non-affected side in 3 cases, there was no bolus passage in 11 cases, and in 15 cases, it was not clear. In the chronic phase, they found that bolus passage occurred dominantly on the non-affected side in 25 cases, there was no bolus passage in 4 cases, and in 1 case it was not clear. In a study involving 29 cases of Wallenberg's syndrome, Mitsuishi et al. studied changes in the side of bolus passage at the CP over time\textsuperscript{6}. They found that the bolus: passed on the non-affected side in 17 cases and remained unchanged; changed from non-passing to passing on the non-affected side in 2; changed from the non-affected side to both sides in 1; changed from non-passing to the affected side and then to the non-affected side in 1; changed from the affected side to the non-affected side in 3; changed from the affected side to both sides and then to the non-affected side in 2; passed on the affected side and remained unchanged in 3. It has been suggested that bolus passage on the non-affected side usually continues, and that bolus passage dominantly on the non-affected side is frequently encountered during the chronic stage in Wallenberg's syndrome patients. However, it must be remembered that some patients had bolus passage dominantly on the affected side or the side of passage changed from the acute to the chronic stage\textsuperscript{5,6}.

The side of bolus passage at the CP may be affected by a disturbance in opening function and its laterality at the CP. The mechanism in cases in which the bolus passes on the affected side at the CP is still controver-

sial. In our preliminary study on the laterality of bolus passage in the CP, we found that, in some cases, a bolus dominantly passed through the affected side. It was postulated that this was related to the side of passage in the TP. To the best of our knowledge, no study has been published that has examined the side of bolus passage at the CP and the TP.

1. The laterality of bolus passage in the TP

In the TP, it was found that the proportion of cases in which bolus passage was dominantly on the affected side was high in the early stage of disease. Over time, this proportion gradually decreased, while that of cases with bolus passage on both sides increased (Fig. 2). Based on VF and videoendoscopic findings of the present cases, it was thought that asymmetric pharyngeal contraction might be responsible for bolus passage dominantly on the affected side during the early stage of disease. In Wallenberg’s syndrome patients, the pharyngeal constrictor is paralyzed due to dysfunction of the premotor neurons in the nucleus ambiguus; the pharyngeal constrictor on the affected side is flaccid, while the constrictor on the non-affected side contracts normally. Thus, on swallowing, the bolus is pushed into the pharyngeal cavity on the affected side, leading to the bolus passing dominantly on the affected side in the TP. In Fig. 5, the videendoscopic findings of Case 2 show that a cavity still remains at the time of swallowing due to the atonic pharyngeal constrictor on the affected side. Figure 6 is a frontal VF image of Case 4, in which a bolus was delivered to the affected side in response to swallowing.

Over time, the paralysis on the affected side improved, leading to a smaller difference between the right and left side contractions. Thus, in the TP, the bolus passage pattern may change from being dominantly on the affected side to being on both sides.

2. The bolus passage side in the CP

2-1. The mechanism that causes laterality

In Wallenberg's syndrome, bolus passage dominantly on the non-affected side occurs in some cases, while bolus passage dominantly on the affected side can also occur. Bolus passage dominantly on the non-affected side was considered to be caused by opening dysfunction on the affected side of the CP. In many cases of bolus passage dominantly on the non-affected side, during the chronic stage of the disease, it was reported that the pressure in the affected side CP did not decrease to 0 mmHg or increased due to the
discrepancy of timing between pharyngeal constriction and opening of the CP (incoordination of the cricopharyngeal muscle). Neurogenic atrophy of the cricopharyngeal muscle on the affected side occurs due to the disturbance present in the nucleus ambiguus, and disuse atrophy or stenosis of the muscle or of its surrounding tissue occurs due to the fact that a bolus cannot pass on the affected side of the CP for a prolonged period of time. These can result in dysfunction of opening of the CP on the affected side, which may lead to bolus passage dominantly on the non-affected side.

In the present study, the bolus passed dominantly on the affected side in 8 patients, which is similar to the results reported by Mitsuishii et al. Passage of the bolus dominantly on the affected side is thought to occur when the opening state of the CP is better on the affected side than on the non-affected side. In particular, in patients with incoordination of the cricopharyngeal muscles bilaterally along with paresis of the cricopharyngeal muscle on the affected side, the cricopharyngeal muscle on the non-affected side does not open on swallowing due to incoordination; however, the affected side is flaccid and can be mechanically opened by the forward movement of the larynx, which probably leads to the bolus passing dominantly on the affected side. Cases 1 and 2 appeared to have had cricopharyngeal muscle incoordination and atonic paresis of the cricopharyngeal muscle on the affected side. Therefore, in these cases, no passage of the bolus was observed in the CP with the head rotated to the affected side, while the bolus passed little by little with rotation of the head to the non-affected side (Table 4).

Because of the association between the passages in the TP and CP, in cases in which the bolus passed
through the TP on the affected side before or following the swallowing reflex, the boluses appear to pass through the CP on the affected side. In Cases 3-8, it was thought that the bolus passed dominantly on the affected side in the CP as a result of having passed dominantly on the affected side in the TP (Table 4). In Cases 3-7, it was thought that passage of the bolus dominantly on the affected side in the TP began soon after disease onset due to the lateralization of pharyngeal constriction on swallowing, resulting in the bolus passing dominantly on the affected side in the CP. In these cases, head rotation to the affected side rather than to the non-affected side was effective; this suggests that opening of the non-affected side CP was not disturbed.

When a compensatory swallowing approach has been determined, evaluations of bolus passage should be done using frontal VF images with both right and left head rotation.

2-2. Changes in proportion of the side that the bolus passed over time

When the time from disease onset was 30 days or less, there were higher proportions of cases in which the bolus passed dominantly on the affected side and

---

**Fig. 6.** Frontal VF findings in Case No. 4
1. Before induction of swallowing reflex. Bolus was seen in the oral cavity.
2. After induction of swallowing reflex, bolus began to enter into the pharynx. In the TP, bolus entered only into the affected side.
3. Bolus was seen to pass through the TP to CP in an affected side dominantly manner.
4. Bolus was seen to pass through the CP on the affected side dominantly.

---
those in which the bolus could not pass, while, when the time from disease onset was greater than 31 days, there were higher proportions of cases in which the bolus passed dominantly on the non-affected side and on both sides.

The bolus may not pass when: the swallowing reflex is not induced, the CP is not opened adequately due to failure of cricopharyngeal muscle relaxation and there is inadequate swallowing pressure due to decreased pharyngeal constriction or failure of velopharyngeal closure. It is thought that the proportion of cases in which the bolus does not pass decreases over time as the remaining intact premotor neurons and the swallowing center begin to work, due to exercises or spontaneously. This subsequently improves the disturbed induction of the swallowing reflex, the coordination of the cricopharyngeal muscle, and the swallowing pressure in the pharynx. However, in our study, the proportion of cases in which the bolus did not pass was greater in patients 181 days or more after disease onset. This is likely due to the fact that chronic patients with severe dysphagia are referred to our hospital from other hospitals.

The proportion of cases in which the bolus passed dominantly on the affected side in the CP was lower in the chronic stage. This may be due to improvement in the CP opening on the non-affected side as a result of improved coordination of the cricopharyngeal muscle on the non-affected side and improved atonic paresis of the cricopharyngeal muscle on the affected side, or the decrease in the proportion of cases in which the bolus passed dominantly on the affected side in the TP over time.

Over time, cases in whom the bolus did not pass or in which the bolus passed dominantly on the affected side changed to being cases in which the bolus passed dominantly on the non-affected side or on both sides. If the proportion of cases in which the bolus passed on both sides in the TP increases, and if the proportion of cases with symmetrical opening of the CP increases over time, then the proportion of cases in which the bolus passed on both sides in the CP will increase.

3. Severity

In almost all cases, the overall severity score at the first evaluation was one or two points; this suggests that relatively severe cases were included in this study (Fig. 4-1). However, the severity improved over time, with a significant difference between the first and final evaluations. Nevertheless, 8 cases still had a severity score of two at the final evaluation, and 3 of these cases were treated surgically.

With respect to bolus passage at the TP, it was expected that the severity of the disease in cases with passage of the bolus on both sides would improve markedly and become the least severe. The proportion of cases in which the bolus passed on both sides might increase over time, along with improvement in the paralyzed pharyngeal constrictor or in the delayed swallowing reflex. However, disease severity improved more in cases in which the bolus passed dominantly on the non-affected sides (Fig. 4-2). This may be due to not only the improvement in the paralysis in the TP but also to various other swallowing functions, including those related to the CP, which can determine the degree of disease severity. In cases in which the bolus passed on the non-affected side in the TP, their severity may have improved because the bolus was apt to enter the non-affected side in the CP, where bolus transit disturbances are less than on the opposite side.

With respect to the side of bolus passage in the CP, cases in which there was non-passage or in whom the bolus passed dominantly on the affected side had a relatively high severity. Some cases in whom the bolus passed dominantly on the affected side had serious symptoms that increased their disease severity, such as a bilateral dysfunction in the CP, delayed onset of the swallowing reflex, or the bolus transport into the affected side at the CP with a bad opening.

At the time of the final evaluation, the cases in which the bolus passed on both sides were found to be the cases whose bilateral CP opening had improved; this effectively reduced the severity of their disease.

Conclusion

Cases in which the bolus passed dominantly on the affected side in the TP were frequently observed during the early stage after disease onset, while cases in which the bolus passed on both sides increased in the chronic stage. The bolus passages in the CP were associated with the passages in the TP. The side of bolus passage in the TP, along with the opening status of the CP, presumably determines the side of bolus passage in the CP.

Passage of the bolus dominantly on the affected side in the CP was considered to occur when CP opening on the affected side on swallowing was maintained to some extent and 1) when the opening of the CP on the
non-affected side was unsuccessful due to incoordination of the cricopharyngeal muscle, or 2) when the bolus passed through the TP dominantly on the affected side.

In the present study, disease severity improved over time; there was a significant difference between the first and final evaluations. In the TP, severity was low in cases in which the bolus passed dominantly on the non-affected side, while the severity was lowest in cases in which the bolus passed on both sides in the CP.

Lastly during the early stage of disease, it seems effective to have a strategy for transporting a bolus that can easily pass through the TP dominantly on the affected side into the non-affected side of the CP with using compensatory methods. If passage of the bolus on the non-affected side is successfully stabilized with improved coordination, as a next step it may be important to try to induce the bolus to pass the affected side of the CP in expectation of the improvement of the bolus passage state in the affected side.

References