J. Phys. Ther. Sci.
24: 387–390, 2012

Two-Dimensional Kinetic Analyses of Swallowing Using Videofluorographic Images of Dysphagia Patients

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Abstract. [Purpose] This studied examine the two-dimensional kinesis of swallowing by patients with dysphagia, based on the movements of contrast material using videofluorography, aiming to design curative programs for aspiration. Videofluorographic two-dimensional examinations of ten patients with aspiration, and another ten without aspiration were used for this study. [Methods] We converted the video record into static images and plotted hyoid bone and laryngeal kinesis on graphs, using two-dimensional image analysis software. Then, we conducted analyses of the trajectory patterns of the hyoid bone and the larynx, and pharyngeal transit time of the contrast material. [Results] Our two-dimensional method revealed significant differences between the two subject groups in maximal forward travel of the hyoid bone, maximal elevation of the larynx, and pharyngeal transit time. [Conclusion] Our findings suggest that aspiration may be caused by a weak pharyngeal contraction and weakened suprahyoid and infrahyoid muscles resulting in inferior kinesis of the epiglottis, and insufficient closure of the laryngeal introitus. For the treatment of aspiration, we believe the application of kinesiotherapy, electric stimulation therapy and replacement therapy should be clinically effective.
Key words : Aspiration, Dysphagia, Two-dimensional kinesis

(This article was submitted Oct. 26, 2011, and was accepted Dec. 13, 2011)

INTRODUCTION

Among the many causes of aspiration that have been discussed are disorders such as coordination disorder of swallowing and respiration, cognitive dysfunction, and kinetic disorder of the hyoid bone and the larynx[1)]. Videofluorographic (VF) examination allows evaluation of both occurrence and severity of aspiration. Currently, the evaluation and treatment strategy for kinesis of the hyoid bone and larynx as well as respiration, which are prime causes of aspiration, are left to the discretion of each therapist in a clinical setting. However, conventional kinetic analysis methods, in which coordinates are set outside of the patient's body, cannot be used for kinetic evaluation of the hyoid bone and larynx, since their coordinates are set inside the body, and also, their kinetic extent is small. Furthermore, it is difficult to grasp the complex swallowing trajectories of the hyoid bone and the larynx in dysphagia patients. There are several available kinetic analysis methods using ultrasonography[2)] and X-ray[3, 4)], however, no study has ever assessed the kinesis of the hyoid bone and the larynx in dysphagia patients. Therefore, this study examined the kinesis of the hyoid bone and the larynx in dysphagia patients using a videofluorographic kinetic analysis method based on the distribution of contrast material and two-dimensional image analysis software, in an attempt to establish a method which can be used for the assessment of aspiration and the design of a treatment strategy.

SUBJECTS AND METHOD

We examined the VF images of ten patients with Grade III aspiration[4)] (average age 67.77 ± 8.23 years, six men and four women, six with functional dysphagia, and four with organic dysphagia) and another ten subjects without aspiration (average age 69.40 ± 8.33 years, eight men and two women, seven with functional dysphagia and three with organic dysphagia). Subjects were selected data blind, except for sex, age, and dysphagia type, functional or organic dysphagia, using 204 VF images taken in FY2007. They were divided into two groups: 116 cases with aspiration and 88 cases without aspiration. Then, the 116 cases were graded into three by stage of severity: 75 Grade I(mild); 31 Grade II(moderate); and 10 Grade III(severe).

Using VF, we recorded kinesis in swallowing. Patients ingested the contrast material several times in the first VF test. The images used were those of the second administration. Images were videotaped at 30 frames per second, and edited frame-by-frame into static images. The Y and X axes were set as coordinates (See Fig. 1). The height of the fourth cervical vertebral body was used as the benchmark of the kinetic extent. Measurement of the kinetic extent started when the contrast material tip reached the epiglottis. Using 2-D image analysis software, DIPP-Motion Pro 2D, the hyoid bone and laryngeal positions were precisely plotted on graphs (See Figs. 2–5). Kinetic analysis of 5 items was performed:

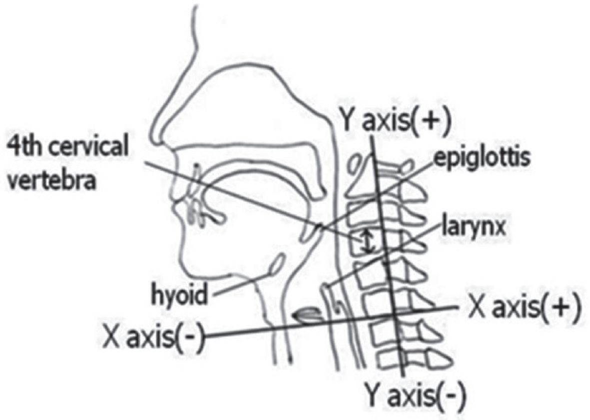

Fig. 1. Locations of the hyoid bone and larynx and setting of X-Y coordinates

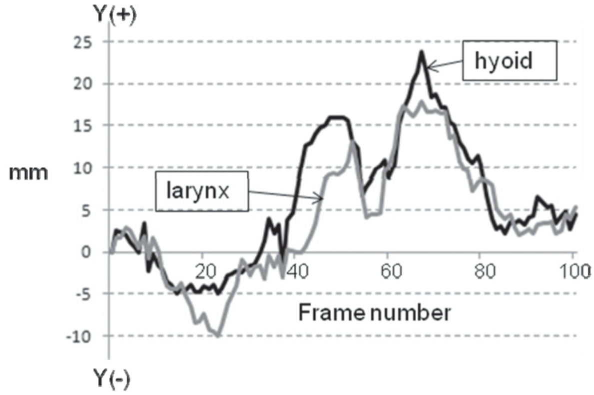

Fig. 3. Larynx and hyoid bone trajectory patterns toward Y-axis of an aspiration case (ID 72, organic dysphagia)

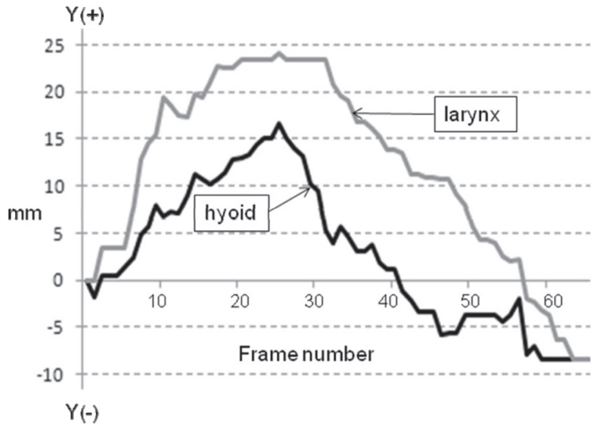

Fig. 2. Larynx and hyoid bone trajectory patterns toward Y-axis of a non- aspiration case (ID 12, functional dysphagia)

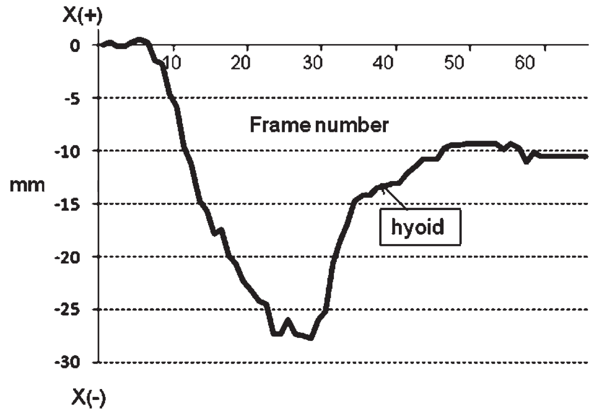

Fig. 4. Hyoid bone trajectory patterns toward X-axis of a non-aspiration case (ID 12)

· trajectory patterns of the two groups
· Y-axis laryngeal kinetic extent
· Y-axis hyoid bone kinetic extent
· X-axis hyoid bone kinetic extent
· pharyngeal transit time: the time of contrast material travel from the epiglottis to the esophageal introitus

The Mann-Whitney test, with a 5% significance level was used for statistical analysis. The study was approved by the Ethical Committee of Nagasaki University Graduate School of Biomedical Sciences.

RESULTS

Two-dimensional Y-axis analyses of the larynx and hyoid bone are shown for both a non-aspiration case, ID 12, functional dysphagia (Fig. 2), and an aspiration case, ID 72, organic dysphagia (Fig. 3). The X-axis trajectory patterns of the hyoid bone are also shown for both a non-aspiration case, ID 12, (Fig. 4), and an aspiration case, ID 72 (Fig. 5).

The maximal Y-axis travel of the larynx was 15.00 ± 8.54 mm in the aspiration group and 27.72 ± 7.22 mm in the non-aspiration group. These image-based results are significantly different. The maximal Y-axis extent of the hyoid bone was 14.49 ± 6.25 mm in the aspiration group and 6.45 ± 7.07 mm in the non-aspiration group. However, there was no significant difference. The X-axis extent of the hyoid bone was 7.82 ± 5.26 mm in the aspiration group and 18.88 ± 7.94 mm in the non-aspiration group, a significant difference. The average pharyngeal transit times in the aspiration and the non-aspiration groups were 3.46 seconds, 104 ± 114.03 frames, and 0.60 second, 18 ± 17.82 frames, respectively, with significant differences (Table 1).

The hyoid bone and larynx of ID 72 showed irregular patterns. Moreover, the hyoid bone showed greater travel than the larynx (Fig. 3). ID 72 demonstrated irregular to-and-fro movement in the hyoid bone and smaller travel then ID 12 (Fig. 5). As determined by the 2D results, swallowing occurred near frame 25 (Fig. 6) in ID 12, and near frame 71 (Fig. 7) in ID 72.

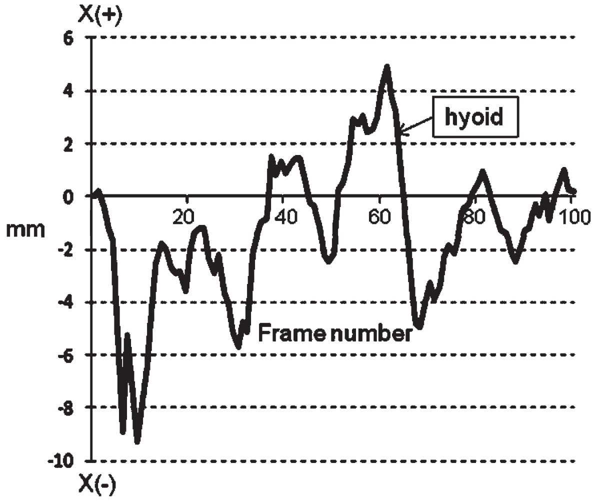

Fig. 5. Hyoid bone trajectory patterns toward X-axis of an aspiration case (ID 72)

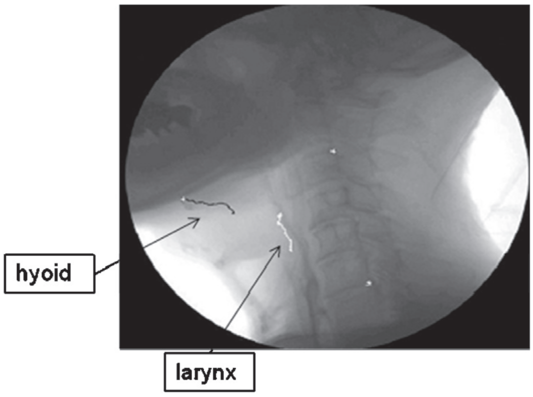

Fig. 6. Traces of the hyoid and larynx on VF from the start to swallow reflex of swallowing (ID 12, functional dysphagia)

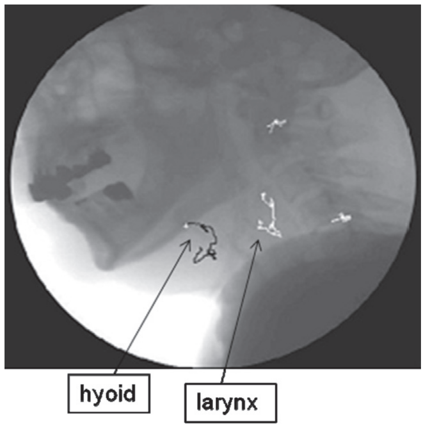

Fig. 7. Traces of the hyoid and larynx on VF from the start to swallow reflex of swallowing (ID 72, organic dysphagia)

DISCUSSION

Our results clearly show a change in trajectory patterns between the two subject groups. Significant differences were demonstrated in pharyngeal transit time, larynx upward and hyoid bone forward kinesis. In ID 12, the movement of the hyoid bone resembled the pattern reported in previous studies[3, 6]. A radiographic study[3] of hyoid bone kinesis in subjects with pharyngolaryngeal discomfort without aspiration reported an almost identical hyoid up-and-down and back-and-forth kinesis. That precious study[3] pointed out that upward kinesis starts slightly earlier than forward kinesis, and Palmer et al.[6] reported in their water swallowing examination of six normal adults that the larynx exhibited greater extent than the hyoid bone in upward direction in videofluorography, while the hyoid bone showed greater extent than the larynx in forward movement in videofluorography. Moreover, when the peak upward and forward positions of the larynx and hyoid bone occur in concert, enlargement of the hypopharynx occurs, enabling a bolus to pass through the pharynx. After all the bolus has entered the esophagus, the larynx and hyoid bone returns to its starting position. ID 12 explains the rapport between past studies[3], and we are confident that a swallow occurred at around frame 25. Regarding pharyngeal transit time, previous studies reported that although there are modulations depending on the amount of bolus and viscosity, it takes about 0.50 second[1, 3, 4] for normal swallowing. In our 2D-specific study, the non-aspiration group took about 0.60 second on average. This suggests that the pharyngeal muscle contraction of this group was sufficiently strong. However, the Y-axis kinesis of the larynx and hyoid bone of ID 72 (Fig. 3) suggests that the prolonged transit time in the aspiration group is due to weakening of the contraction force of the pharyngeal muscles resulting in difficulty in narrowing the distance between the oropharynx and hypopharynx. Moreover, significant differences between the two groups were observed in maximal laryngeal upward kinesis and maximal hyoid bone

Table 1. Item comparison of the aspiration and non-aspiration groups

Items	Aspiration	Non-aspiration
Y-axis travel of larynx	15.00 ± 8.54 mm	27.72 ± 7.22 mm**
Y-axis travel of hyoid bone	14.49 ± 6.25 mm	6.45 ± 7.07 mm
X-axis travel of hyoid bone	7.82 ± 5.26 mm	18.88 ± 7.94 mm**
Pharyngeal transit time	104 ± 114.03 fram	18 ± 17.82 fram**

**p<0.01, *p<0.05, Mean ± SD

forward kinesis. Past studies of normal swallowing found that, laryngeal elevation is greater than that of the hyoid bone. At the beginning of pharyngeal elevation, following suprahyoid muscle activation, the infrahyoid muscle moves. Subsequently, synchronized contraction of both muscles helps the hyoid bone and larynx achieve upward kinesis[3, 7]. In our study, we found significant differences in maximal kinetic extent of the hyoid bone and larynx between the two groups and the different trajectory patterns observed in the aspiration cases may be due to the weakness of the suprahyoid and infrahyoid muscles[3, 5]. Moreover, our results suggest that the weakness of the muscles reduces the kinetic extent and velocity of the hyoid bone and larynx elevation. Consequently, insufficient falling of the epiglottis leads to incomplete closure of the laryngeal introitus. The elevation range and velocity of the hyoid bone and larynx may cause dysphagia. Shaker exercises[10] and neuromuscular electrical stimulation[11] are used to treat swallowing disorders, and the Mendelsohn maneuver is also effective. In the present study, we demonstrated that weakness of pharyngeal muscle contraction and disorders of muscles which support laryngeal elevation and hyoid forward kinesis cause aspiration in swallowing. The limitations of this study include the small sample size and the presence of two types of dysphagia. Since causation of dysphagia might have affected the results, we plan to scrutinize them in relation to dysphagia type[8, 9]. Our method used videofluorographic kinetic analysis of patients with aspiration. However, we cannot exclude the possibility of adverse effect on patients caused by radiation exposure since we used videofluorography for our measurements. Our future objective is to make a kinetic comparison of patients with coordinates attached to their body surface in order to reduce the measurement burden of patients. In the future, investigations involving larger subject numbers and of treatments effects will also be necessary.

ACKNOWLEDGEMENT

We would like to thank Professor Akio Tsubahara for assisting us with the videofluorographic data.

The authors declare that they have no conflict of interest.

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