ABSTRACT


Objective: To determine whether aging influences the position of the leading edge of the bolus during chew swallow as identified using videofluorography (VF).

Methods: Subjects comprising 53 healthy individuals (35 men and 18 women; mean age of 54.5 ± 19.3 years and range of 25–89 years), were subdivided into 4 groups: young adults, middle age, sixties, and seventy and over. Subjects underwent lateral VF to evaluate the position of the leading edge of the bolus just prior to the onset of swallowing, with normal chew swallow for solid foods and swallowing on command for liquids.

Results: For solid foods, the position of the leading edge of the bolus during chewing changed with increasing age. Mastication time and the number of chew cycles increased with increasing age and were much higher in women than in men for the seventy and over group.

Conclusion: For solid foods, the position of the leading edge of the bolus during chewing in the pharynx changed with increasing age; this may affect the number of chew cycles and increasing age. Gender may also affect both of these factors, with women tending to show a deeper transition of the bolus into the pharynx.

Key words: aging, deglutition, chewing, Stage II transport

Introduction

The concept of stage II transport for bolus movement during chewing was recently proposed by Palmer et al. (1,2), suggesting that the bolus is transferred to the oropharynx where it accumulates until the onset of swallowing. Saitoh et al. speculated that chewing reduced the effectiveness of the posterior tongue-palate seal, and as a consequence, the oral contents could easily spill into the pharynx. They also suggested that this mix of foods with different consistencies (both solid and liquid phases) would increase the risk of aspiration (3). In addition, with liquids, part of the bolus might enter the pharynx before the onset of swallowing, particularly in older subjects (4–6). Using videofluoroscopy, it has been reported that the bolus remains in the pharynx of healthy individuals before swallowing in 60% of liquid swallows and 76% of solid food swallows (7). If unintentional entry of liquid into the pharynx is affected by age, at the intake of solid foods, older individuals would show bolus entry into the pharynx during the earlier phase of...
swallowing.

The purpose of this study was to determine whether the position of leading edge of the bolus during chew swallow changes with increasing age.

**Subjects and Methods**

This study comprised 53 healthy individuals (35 men and 18 women; mean age of 54.5 ± 19.3 years and range of 25–89 years) without neurological, pharyngeal, or laryngeal disorders that could provoke dysphagia. All subjects were able to eat regular meals. To clarify the effect of aging, subjects were subdivided into the following 4 groups: young adults, 13 individuals (mean age, 28.5 ± 2.5 years; range, 25–39 years; 8 men and 5 women); middle age, 15 individuals (mean age, 47.4 ± 5.1 years; range, 40–59 years; 8 men and 7 women); sixties, 12 individuals (mean age, 64.8 ± 3.1 years; range, 60–69 years; 10 men and 2 women); and seventy and over, 13 individuals (mean age, 79.2 ± 5.9 years; range, 70–89 years; 7 men and 6 women). Written informed consent was obtained from all subjects prior to enrolment. The Medical Ethics Committee of Fujita Health University approved the design of this study.

With regard to use of dentures, the young adult and middle age groups did not include any individuals who used dentures. The group of sixties included only 1 subject with partial dentures. Among the seventy and over group, 5 used complete dentures, 3 subjects used partial and complete dentures, 4 subjects used partial dentures, and 1 subject did not use dentures; all of the subjects who customarily wore dentures used their dentures during this study.

Each subject was seated comfortably in a chair and videofluorography (VF) was performed at 30 frames/s from a lateral perspective. Each subject consumed the following foods: 50% w/v liquid barium with the command to swallow (COM), corned beef hash with barium (CB), and a shortbread cookie with barium paste (CK). For the liquid barium, 10 mL of liquid barium was placed in the mouth using a syringe, and the subject was instructed to swallow. For CB and CK, 8 g of food was placed in the mouth of each subject, and they were directed to chew it thoroughly; for these tests, the subjects were not instructed how to eat, but permitted to eat the food in the manner they preferred. We assumed that the position of the leading edge of the food in the pharynx before the onset of swallowing would be affected by the processing time of the food in the mouth, which in turn would depend on the degree of chewing before swallowing.

For each kind of food, 2 trials were performed, with a total of 6 trials for each subject. Overall, 311 VF recordings of swallowing at 30 frames/s were recorded and analyzed on a personal computer using video-editing software (iMac DV model and iMovie, Apple). Of these, 7 VF recordings had to be excluded due to technical difficulties with recording. Slow-motion, still-picture, and reverse-replay functions were used to review the VF recordings.

Each type of swallowing was evaluated to detect the position of the leading edge of the bolus just before the initiation of the hyoid movement, and the number of chew cycles. We defined the start of swallowing as the initiation of hyoid movement (IHM).

According to the anatomy of the oropharyngeal areas (Fig. 1), the position of the leading edge of the bolus was identified in the VF image frame at IHM, as follows: oral cavity area (OC), upper oropharynx area (UOP; on the lateral view, beyond the border between the hard and soft palates and up to the lower edge of the mandible extend to the posterior), vallecular area (VAL; beyond the lower edge of the mandible and up to the vallecular), and hypopharynx area (HYP; beyond the vallecular and up to the beginning of the esophagus). Mastication time was defined as the duration from the point at which the bolus started to change shape between the upper and lower teeth after being placed in the oral cavity until the end of jaw movement. For each mastication time, the number of chew cycles was also counted.

To determine whether the position of leading edge of the bolus changed with age, we compared distributions of the bolus position using χ² analysis and calculated the value of post-hoc cell contribution. The results of the post-hoc cell analysis were presented with numerical values (no unit), and the order of the results were estimated by the degree of those values. For comparisons of mastication time and number of chew cycles for CB and CK, one-way analysis of variance and the Tukey-Kramer honestly significant difference test were used. The logistic regression

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Figure 1. Classification of oropharyngeal areas and position of the leading edge of a bolus were defined as follows in the VF image frame at the start of swallowing.

OC : oral cavity area
UOP: upper oropharynx area
VAL : vallecular area
HYP: hypopharynx area

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analysis was performed using gender, mastication
time, number of chew cycles, and use of dentures as
the independent variables and the position of the
leading edge of the bolus as the dependent variable to
confirm the relationship between these factors.
Statistical procedures were performed with Statview
version5 (SAS; USA).

Results

1. Position of the leading edge of the bolus

Prior to the onset of swallowing, we observed
significant differences in the position of the leading
edge of the bolus (Table 1) across the age groups for
swallowing COM ($\chi^2 = 32.822, p < 0.001$) and CB ($\chi^2
=21.184, p=0.0119$). The post-hoc cell contributions
to COM were 3.938 for OC in the young adult group
and 2.613 for VAL and 1.952 for HYP in the seventy
and over group. Conversely, the post-hoc cell

Table 1. Leading edge position of bolus just before the initiation of hyoid movement

<table>
<thead>
<tr>
<th>Young adults</th>
<th>COM</th>
<th>CB</th>
<th>CK</th>
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<tbody>
<tr>
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<td>N PHCC</td>
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<tr>
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<tr>
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<td>26</td>
<td>26</td>
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<tr>
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<td>30</td>
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<tr>
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<tr>
<td>P of chi square</td>
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<td>0.0645</td>
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</table>

OC : Oral cavity area, UOP : Upper oropharyngeal area
VAL : Vallec Aurea, HYP : Hypopharyngeal area
COM : 10 ml of barium (50% w/v) for command swallow
CB : 8 g of corned beef hash with barium
CK : 8 g of short bread cookie with barium
N : number of trials
PHCC : Post-hoc cell contribution rate

contribution for HYP was -3.389 in the young adult group. These results suggested that in terms of command to swallow with liquid, subjects in the young adult group were able to retain the bolus in their mouths, making the position of leading edge of bolus in the pharynx higher than those in the seventy and over group. In terms of the post-hoc cell contribution of CB, maximum values in each age group were 1.741 for OC in the young adult group, 2.332 for UOP in the middle age group, 1.395 for VAL in the sixties group, and 3.567 for HYP in the seventy and over group. These results suggest that the position of the leading edge of the bolus prior to the onset of swallowing gradually transitioned to a deeper position with advancing age. However, the position of the leading edge of the bolus across the 4 age groups was not significantly different with CK ($\chi^2 = 16.117, p = 0.0645$).

For the post-hoc cell contribution of subjects in the middle age group and the sixties group, all the values were distributed between -1.7 and 1.8, and none of them were as big as the values. No remarkable differences were observed in the young adult group and in the seventy and over group.

2. Mastication time and number of chew cycles

Mastication time and the number of chew cycles increased with age (Fig. 2) for swallowing both CB and CK and were also significantly higher in the sixties group and the seventy and over group than in the young adult and middle age groups. The mean number of chew cycles for CB was significantly higher in women (26.2 ± 20.80) than in men (17.2 ± 10.25; $p < 0.05$), as was the mean number of chew cycles for CK (38.3 ± 21.27 in women vs. 28.9 ± 13.75 in men, $p < 0.05$). Figure 3 shows the relationship between the number of chew cycles and age for swallowing CK. Overall, the results showed that the number of chew cycles increased with age and was particularly higher for women and for the seventy and over group.

3. Logistic regression analysis

We repeated these analyses and modified the division of samples for each of the independent factors such as age, mastication time, and the number of chew cycles. However, we were unable to identify any significant relationships aside from the gender differences for the differences in swallowing CK. This may be because of our small sample size. When swallowing CK, women tended to show earlier...
transition of the bolus into the pharynx than men (Table 2). We did not identify any significant differences for swallowing CB.

**Discussion**

Feldman et al. reported that tooth loss significantly increased the duration of mastication until swallowing and the size of particles that the subject was willing to swallow (8). From the results of present study, it was confirmed that the mastication time and the number of chew cycles increased with age for solid foods. As there was a possibility that the number of samples was small, from the results of logistic regression analysis we were unable to determine whether mastication time and the number of chew cycles significantly affected to the degree of bolus transition into the pharynx. As for the other factors, although we were unable to identify any determinant factors for CB, the results of the logistic regression analysis for CK showed a significant relationship for gender, with women tending to show an earlier transition of the bolus into the pharynx than men. In a study of oropharyngeal swallowing in different ages, Robbins et al. observed that women showed a longer duration of upper esophageal sphincter opening (5). They suggested that this finding was related to the smaller size of the female head and neck anatomy. From our results for swallowing CK, the number of chew cycles was markedly higher in women seventy and over group. Entry of the bolus into the pharynx during chewing might be affected by the number of chew cycles and age, both of which may be linked to gender.

It has been reported that sensory discrimination in the oral cavity and pharynx progressively diminishes with age, and the threshold for the onset of pharyngeal swallowing also increases with age. Aviv et al. suggested that this decreased sensory discrimination was caused by the age-related loss of superior laryngeal nerve innervation (9). Shaker et al. indicated that
threshold for the onset of pharyngeal swallowing and the pharyngoglottal closure reflex increases in the elderly (10,11). In the present study, even for solid food, the position of the leading edge of the bolus changed with increasing age. The tendency for the bolus head to easily reach the pharynx beyond the epiglottis before the initiation of swallowing in the elderly could also be a result of decreased sensitivity and increased reflex threshold in the pharyngeal area. In the elderly, this decreased sensitivity and increased reflex threshold may cause the bolus to easily reach the pharynx beyond the epiglottis before the onset of swallowing.

Shaker et al. indicated that elderly persons have also been noted to show a lack of coordination between deglutition and respiration (12). In addition, an autopsy study by Mortelliti et al. reporting a significant age-related loss of myelinated nerves in the superior laryngeal nerve (13). The superior laryngeal nerve plays a crucial role in sensation in the larynx. Kikuchi et al. also showed that 71% of elderly persons diagnosed with community-acquired pneumonia were later shown to have silent aspiration; only 10% of healthy age-matched subjects show this same diagnosis (14). The combination of premature transition of the bolus into the pharynx and decreased sensitivity of the larynx might be contributing factors to silent aspiration of food during chewing in the elderly.

Conclusion

Mastication time and number of chew cycles increase with age for solid foods. Entry of the bolus during chewing in the pharynx; this may affect the number of chew cycles and increasing age. Gender may also affect both of these factors. For solid foods, the position of the leading edge of the bolus changed with increasing age, showing a tendency for the head of the bolus to easily reach the pharynx beyond the epiglottis before the initiation of swallowing in elderly persons. This tendency may result from a decreased sensitivity and increased reflex threshold in the pharyngeal area. This premature transition of the bolus into the pharynx and decreased sensitivity of the larynx may cause silent aspiration of food during chewing in elderly persons.

References