

ORIGINAL ARTICLE

Initiation of Pharyngeal Response during Discrete Swallowing and Chew-swallowing in Healthy Subjects

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Objective: The aim of this study was to measure the initiation of pharyngeal swallowing during discrete swallowing and during chew-swallowing in younger and older healthy subjects and to determine the normal range of the stage transition duration (STD) for different food boluses. The correlations between STDs were investigated. **Methods:** Twenty-eight younger subjects (< 60 years old) and 25 older subjects (≥ 60 years old) were enrolled. While in the sitting position, the subjects swallowed 10 ml of thin liquid barium (LQ), 8 g of corned beef hash with barium (CB), 8 g of cookie with barium (CK), and a two-phase mixture of 4 g of corned beef hash with barium and 5 ml of thin liquid barium (MX). A videofluoroscopic examination of swallowing was performed at 30 frames/s in the lateral projection. The delay in pharyngeal swallowing (i.e., STD) was measured. The normal range (mean \pm 2SD) of STDs for each bolus type was determined, and correlations were calculated to examine the relationship among STDs. **Results:** The median STDs for LQ, CB, CK, and MX in all subjects were 0.0, 1.2, 2.4, and 1.9 s, respectively. The STDs were prolonged for CB, CK, and MX compared with LQ. Additionally, the median STD was longer for LQ, CB, and CK in older than in younger subjects. No significant correlations were found between STDs except for those between CB and CK. **Conclusions:** A delayed pharyngeal response is commonly observed during chew-swallowing. Liquids, solids, and two-phase mixtures exhibit independent timings of pharyngeal swallow initiation.

Key Words: chew-swallowing; discrete swallowing; dysphagia; stage transition duration

INTRODUCTION

Dysphagia can cause aspiration. Independent predictors of aspiration include residue in the valleculae, piriform sinuses, and on the walls of the hypopharynx; reduced hyoid elevation; dysfunction of the epiglottis; and delayed initiation of the pharyngeal swallow.¹⁾ The stage transition duration (STD) has been proposed as a measure of the delay in the pharyngeal stage of swallowing.²⁾ STD is measured from the moment at which the bolus passes the lower border of the ramus of the mandible to the time at which the maximal excursion of the hyoid is initiated. Studies have compared STDs between younger and older subjects and reported that

STD values for liquid were 0 or negative in young healthy individuals. In addition, STD increases with age, and older subjects have significantly longer values.²⁻⁴⁾ Prolonged STD values, which can occur in stroke patients, are associated with an increased risk of aspiration because the safety of swallowing is compromised.^{5,6)} An STD of up to 0.5 s or even 0.75 s may be completely safe, whereas an STD approaching 0.9 or 1.0 s may be considerably more dangerous.⁶⁾

Although the majority of studies have assess STD for drinking liquid, chewed solid food may be transported to the pharynx (stage II transport) up to 10 s before swallow onset in healthy subjects. It is not the food consistency but rather the chewing that contributes to stage II transport. Chewing

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may continue while food accumulates in the oropharynx. Posterior tongue–soft palate contact is lost during chewing, resulting in the early movement of a bolus from the oral cavity to the pharynx.^{7–9} A study showed that prolonged STDs during chew-swallowing were not associated with aspiration in stroke patients.¹⁰ In stroke patients, the pharyngeal swallow delay that occurs during chew-swallowing may be different from that during the discrete swallow of liquid. The aim of this study was to measure the initiation of pharyngeal swallowing during a discrete swallow and during chew-swallowing for healthy subjects, to determine the normal range of STDs for various types of foods, and to evaluate the relationship between STDs.

METHODS

A total of 28 younger subjects (< 60 years old) and 25 older subjects (≥ 60 years old) were recruited. There were 16 men and 12 women in the younger group (mean age, 39 ± 10 years) and 17 men and 8 women in the older group (72 ± 9 years). Subjects were included in the study if they had no history of neurological or physiological problems related to deglutition and no complaints of dysphagia. This study was approved by the institutional review board, and written informed consent was obtained from all subjects.

The videofluoroscopic swallowing examination was performed at 30 frames/s in the lateral projection. While in the sitting position, the subjects swallowed 10 ml of thin liquid barium (LQ), 8 g of corned beef hash with barium (CB), 8 g of cookie with barium (CK), and a two-phase mixture of 4 g of corned beef hash with barium with 5 ml of thin liquid barium (MX) twice for each bolus type. Subjects were instructed to drink LQ and to chew CB, CK, and MX because the discrete swallowing of LQ and the chewing of CB, CK, and MX reflect normal swallowing processes.⁹ STDs were calculated, and the average data were determined for the two swallows. STDs in younger and older subjects were compared. The normal range of STD for each bolus type was determined by calculating the mean \pm 2SD. Correlations were calculated to examine the relationship between the STDs of the different bolus types.

STATISTICAL ANALYSIS

Normality was evaluated using the Shapiro–Wilk test. Wilcoxon’s signed-rank test with Bonferroni correction was applied to assess the differences in STDs for each bolus type. STDs in younger and older subjects were compared using the

Mann–Whitney U test. Spearman rank correlation coefficients were used to examine the relationships between STDs for LQ, CB, CK, and MX. All analyses were performed using SPSS version 19 (IBM Corporation, Armonk, NY, USA). P values of <0.05 were considered statistically significant.

RESULTS

None of the STD values for any of the bolus types were normally distributed. The median STDs for LQ, CB, CK, and MX were 0.0, 0.4, 2.0, and 1.8 s, respectively, in younger subjects; 0.1, 4.4, 4.2, and 1.9 s, respectively, in older subjects; and 0.0, 1.2, 2.4, and 1.9 s, respectively, for all subjects. The STD for LQ was significantly shorter than that for CB, CK, and MX in younger, older, and all subjects [$P < 0.001$, except for LQ vs. CB in younger subjects ($P = 0.018$)]. The STDs for LQ ($P = 0.015$), CB ($P = 0.002$), and CK ($P = 0.007$) were significantly longer in older subjects than in younger subjects, whereas MX showed no significant differences between younger and older subjects. **Figure 1** shows the correlations between STDs for LQ, CB, CK, and MX. We found no significant correlations between STDs, except for those between CB and CK. Additionally, we converted STDs to normal distributions by logarithmic transformation, and the normal ranges of the STDs were determined using the normalized mean value \pm 2SD (**Table 1**).

DISCUSSION

We found that STDs were prolonged during chew-swallowing when compared with those during the discrete swallowing of liquid. Moreover, STDs for LQ, CB, and CK were longer in healthy older subjects than those in younger subjects. The normal range of STDs during a discrete swallow of liquid in healthy subjects was -0.4 to 1.6 s for all ages, which is consistent with those reported in earlier studies.^{2,4–6} The prolonged STD in chew-swallowing derives from stage II transport, whereby the chewed boluses may be transported to the pharynx before the initiation of pharyngeal swallowing.^{7–9} When older subjects ate CB or CK, the median STDs were less than 5 s, whereas the upper limit of normal STDs for CB and CK is greater than 50 s. We suggest that the initiation of pharyngeal swallowing is impaired with aging and that the efficiency of mastication varies between individuals, particularly among healthy older subjects. In contrast, we found that the STD for MX was not affected by age.

Our results suggest that the mechanisms initiating the pharyngeal response differ between MX and other boluses.

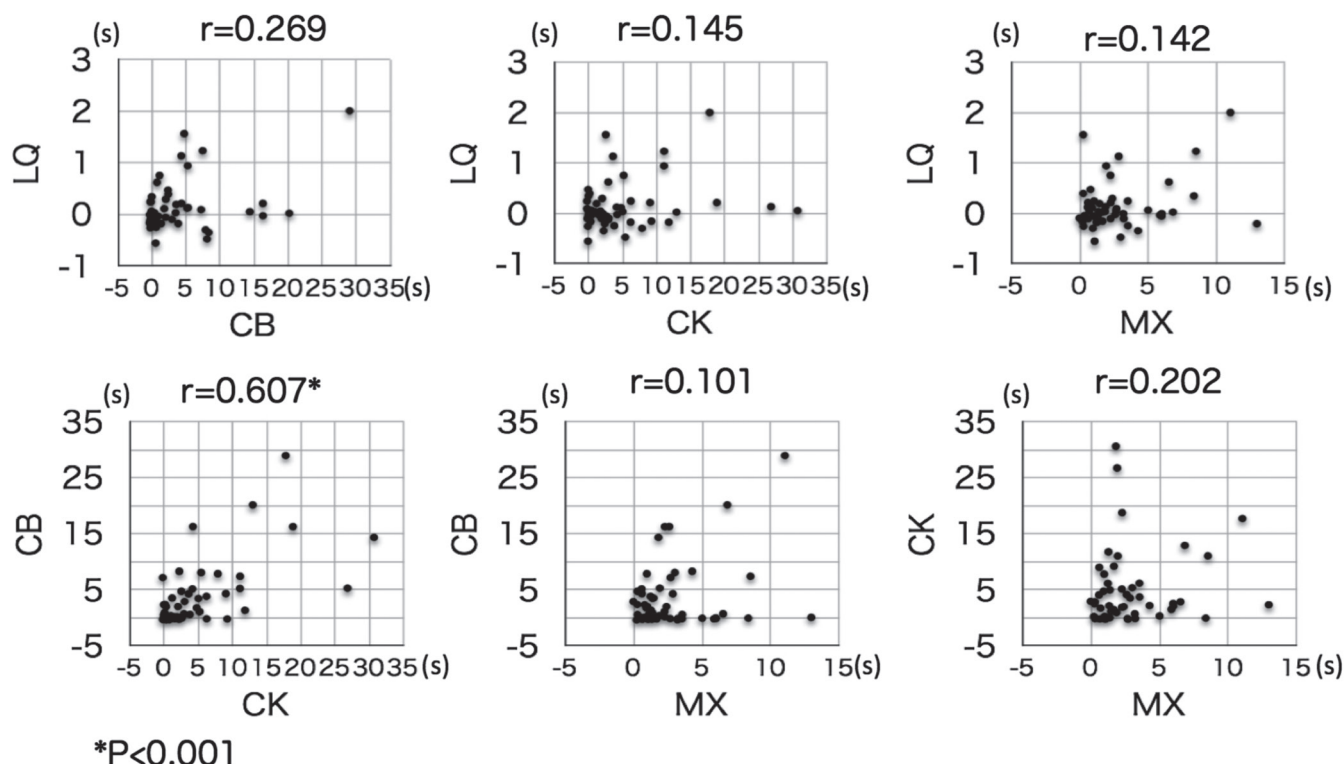


Fig. 1. Correlations between stage transition durations (STDs) for LQ, CB, CK, and MX. The only significant correlation between STDs was that between CB and CK. LQ, 10 ml of thin liquid barium; CB, 8 g of corned beef hash with barium; CK, 8 g of cookie with barium; MX, a two-phase mixture of 4 g of corned beef hash with barium and 5 ml of thin liquid barium.

Because the leading edge of the bolus in healthy subjects is significantly lower in the foodway at the onset of swallowing with MX than for other bolus types,⁹⁾ protective airway mechanisms that prevent aspiration may be preferentially activated. Moreover, except for that between CB and CK, we found no significant correlations in STDs between the bolus types. Therefore, those subjects with a longer STD for CB may also have a longer STD for CK, whereas those subjects with a longer STD for LQ do not necessarily have longer STDs for CB, CK, or MX. In other words, STDs for CB, CK, and MX cannot be predicted from the results of STDs for LQ. Because CB and CK are both solid foods, we suggest that liquids, solid food, and two-phase mixtures exhibit independent timings of pharyngeal swallow initiation. Consequently, at least three types of boluses, i.e., liquid, chewable foods, and mixtures, should be used to evaluate STDs.

A limitation of this study was that we evaluated only normal subjects, and delayed pharyngeal swallow response in normal subjects does not cause aspiration. A previous study reported that prolonged STDs for MX were not linked to aspiration in stroke patients¹⁰⁾ but that prolonged STDs in patients with dysphagia might lead to aspiration of other

types of boluses. This raises the question of what governs the timing of pharyngeal swallow initiation for liquids, solid food, and two-phase mixtures. Further studies are needed to elucidate the mechanisms causing the delayed initiation of the pharyngeal response during chew-swallowing.

In conclusion, a delayed pharyngeal response is commonly observed during chew-swallowing. Liquids, solid food, and two-phase mixtures exhibit independent timings of pharyngeal swallow initiation. Therefore, the reasons for delayed pharyngeal responses during chew-swallowing should be examined in further studies.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

Table 1. Median and normal range of STD

		< 60 years old	≥ 60 years old	All ages
LQ (s)	Median	0.0	0.1	0.0
	Normal range	−0.4 to 1.2	−0.4 to 2.0	−0.4 to 1.6
CB (s)	Median	0.4	4.4	1.2
	Normal range	−0.5 to 7.8	−0.4 to 51.2	−0.5 to 26.0
CK (s)	Median	2.0	4.2	2.4
	Normal range	−0.3 to 12.0	−0.3 to 58.1	−0.4 to 30.4
MX (s)	Median	1.8	1.9	1.9
	Normal range	0.0 to 10.0	0.0 to 11.9	0.0 to 10.7

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