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Original Article

The risk of laryngeal penetration or aspiration among discrete, sequential, and chew-swallowing

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ABSTRACT
Ogawa M, Kagaya H, Ozeki M, Kikumura K, Shibata S, Saitoh E. The risk of laryngeal penetration or aspiration among discrete, sequential, and chew-swallowing. Jpn J Compr Rehabil Sci 2019; 10: 77−81.

Objective: To compare three different types of swallowing—discrete swallowing, sequential swallowing, and chew-swallowing—in terms of the risk of laryngeal penetration and aspiration.

Methods: Between January 2011 and May 2016, 136 patients underwent videofluoroscopic examination of swallowing without the use of compensation techniques while they swallowed 10 mL of liquid (discrete swallowing: LQ10), 30 g of liquid from a cup (sequential swallowing: CUP30), and a mixture of 5 mL of liquid and 4 g of corned beef (chew-swallowing: MX) in the sitting position. We assessed the presence or absence of laryngeal penetration and aspiration during swallowing the three types of boluses. The degree of difficulty and Penetration-Aspiration Scale (P-A Scale) for each bolus were investigated using McNemar's test and Spearman's rank correlation coefficient, respectively.

Results: Laryngeal penetration was observed in 73 patients for LQ10, 62 for MX, and 97 for CUP30, indicating that there were significantly more patients for CUP30 than LQ10 ($p < 0.001$) and MX ($p < 0.001$). Aspiration was observed in 8 patients for LQ10, 14 for MX, and 20 for CUP30. There were significantly more cases of aspiration for CUP30 than LQ10 ($p = 0.009$). The correlation coefficients for the P-A Scale for each bolus were $\rho = 0.370$ for LQ10 and CUP30 ($p < 0.001$), $\rho = 0.100$ for MX and CUP30 ($p = 0.312$), and $\rho = -0.202$ for MX and LQ10 ($p = 0.055$).

Conclusions: The frequency of laryngeal penetration was highest for CUP30, followed by that for LQ10 and MX; the frequency of aspiration was highest for CUP30, followed by that for MX and LQ10. There was no statistically significant correlation for P-A Scale between MX and LQ10 nor MX and CUP30.

Key words: discrete swallowing, sequential swallowing, chew-swallowing, laryngeal penetration, aspiration

Introduction

Swallowing is one of the daily activities and humans typically consume a wide variety of food and drinks. Swallowing is not a single action. Rather, the process of swallowing liquids consists of the following four stages, collectively referred to as "The Four Sequential Model" [1]: the oral preparatory stage, the oral propulsive stage, the pharyngeal stage, and the esophageal stage. The characteristic sequence when swallowing liquids consists of the bolus being propelled to the pharyngeal region during the oral propulsive stage, followed immediately by the pharyngeal stage during which the swallowing reflex occurs. During discrete swallowing of liquids, the larger the amount taken into the mouth, the higher is the risk of laryngeal penetration and aspiration [1, 2]. Aspiration is more likely to occur when drinking a mouthful of liquid from a cup than when drinking 5 mL of liquid from a spoon, and aspiration is less likely to occur when drinking a thick liquid than when drinking a thin liquid [3]. In contrast, when liquids are continuously swallowed using a cup or straw (sequential swallow), on the triggering of the swallowing reflex, the leading edge of the bolus often reaches the hypopharynx, which is deeper than discrete swallowing [4, 5]. Laryngeal penetration and aspiration are assessed on an 8-step scale known as the Penetration-Aspiration Scale (P-A Scale: 1. No laryngeal penetration,

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2–5. Laryngeal penetration, 6–8. Aspiration) [6]. A study that utilized this scale in healthy elderly volunteers and patients with mild acute stroke reported that sequential swallowing showed significantly higher scores on the P-A Scale than on discrete swallowing of 3, 5, 10 and 20 mL [5].

In contrast, swallowing a solid that requires chewing, that is, chew-swallowing, has been described in recent years through the use of a process model. Palmer et al. [7, 8] showed that before the start of the swallowing reflex and while an individual was still chewing, the chewed food was transported from the fauces to the oropharynx (Stage II transport) where a bolus was collected and formed. It has been reported that during chew-swallowing, the bolus may be transported to the pharynx in up to 10 s before swallow onset in healthy subjects. In particular, when chew-swallowing a mixture of solid and liquid foods, even healthy individuals experience the onset of the swallowing reflex after the liquid part of the bolus has reached the hypopharynx, which is at a deeper level than during chew-swallowing, resulting in an increased risk of aspiration [9, 10].

As mentioned above, discrete swallowing, sequential swallowing, and chew-swallowing differ; therefore, it would be clinically useful to identify the form of swallowing that is more likely to result in laryngeal penetration and aspiration. Thus, the present study conducted a retrospective investigation to compare three different types of swallowing—discrete swallowing of liquid, sequential swallowing of liquid, and chew-swallowing of a mixture of solid food and liquid—in terms of the risk of laryngeal penetration and aspiration.

Methods

This study was conducted after receiving approval from the institutional review board (HM18-524). The subjects were patients with dysphagia or those suspected of having dysphagia who underwent videofluoroscopic examination of swallowing (VF) at our hospital between January 2011 and May 2016 after the patients or their proxies provided written informed consent. Patients who were able to ingest boluses comprising 10 mL of liquid (discrete swallowing: LQ10), 30 g of liquid from a cup (sequential swallowing: CUP30), and a mixture of 5 mL of liquid and 4 g of corned beef (chew-swallowing: MX) without using any compensation techniques while in the seated position and whose lateral images could be obtained were included. Patients in whom it was impossible to obtain images from the time point at which the bolus entered the oral cavity until the conclusion of swallowing and those whose images were unclear and could not be used to determine the presence of laryngeal penetration and aspiration accurately were excluded. We assessed the presence or absence of laryngeal penetration and aspiration during swallowing the three types of boluses by reviewing the VF recordings of the included patients.

VF was performed using 50% wt/vol barium (Barytogen Sol, Fushimi, Kagawa, Japan), and X-ray fluoroscopy was performed at 30 frames/s. When the patients performed LQ10, 10 mL of liquid barium was injected into the floor of their mouths using a syringe, and they were then asked to swallow at once. When performing CUP30, the patients were handed a cup containing 30 g of liquid barium and instructed to drink it as they normally would. When performing MX, 4 g of corned beef and 5 mL of liquid barium were administered into the patients' mouths, and they were instructed to chew and swallow the mixture as they normally would. Each trial of LQ10, CUP30, and MX was performed one time, and laryngeal penetration and aspiration were assessed by using the P-A Scale [6]. In consideration of the patients' safety, when there were clear indications of aspiration even before the patients swallowed the entire 30 g of liquid during the CUP30 test, they were immediately stopped. The P-A Scale assessments for all tests were determined via agreement of at least two physiatrists.

When comparing the results for two boluses, if, for example, one attempt resulted in aspiration and the other did not, the figure arrived at by dividing the smaller number of such patients by the larger number of such patients was defined as the inconsistency rate (IR). In the IR range of 0–1, when no patients experienced aspiration of bolus A but some patients experienced aspiration of bolus B, this was rated as IR 0. Doing so clearly showed a difference in the level of difficulty associated with the aspiration of bolus A and bolus B. In contrast, when IR is 1, it indicates that the number of patients who experienced aspiration with bolus A but no aspiration with bolus B was the same as the number of patients who experienced no aspiration with bolus A and aspiration with bolus B, indicating that it was difficult to determine the ranking of difficulty associated with aspiration of bolus A and bolus B. In some cases, such as no aspiration with both bolus A and bolus B, IR cannot be calculated (Table 1).

The severity of dysphagia was assessed using the Dysphagia Severity Scale (DSS) [11]. DSS is an ordinal scale consisting of the following seven steps:

Table 1. Definition of inconsistency rate.

		Bolus B	
		+	−
Bolus A	+	a	c
	−	b	d

$$\text{Inconsistency rate (IR)} = \begin{cases} b/c & (b \leq c) \\ c/b & (b > c) \end{cases}$$

1) saliva aspiration, 2) food aspiration, 3) water aspiration, 4) occasional aspiration, 5) oral problems, 6) minimum problems, and 7) within normal limits.

Statistical analyses were performed using SPSS Statistics version 23 (IBM Corporation, USA). Two comparisons of the degree of difficulty were conducted for each of the three types of boluses for a total of three tests. The standard of significance for these tests was determined to be 5%, using the McNemar test with Bonferroni correction. The P-A Scale for each bolus was investigated using Spearman's rank correlation coefficient after excluding P-A Scale of 1 (no laryngeal penetration, no aspiration) from each, because when the dysphagia becomes milder, the number of P-A Scale 1 patients increases, and the correlation becomes high with any boluses.

Results

A total of 136 patients were enrolled in this study: 99 men and 37 women. The mean age of the patients was 71 (34–97) years. The main pathological causes of dysphagia, in descending order, were stroke, respiratory disease, and neuromuscular disease. DSS indicated a large number of "occasional aspiration" and "minimum problems," with the median value at "oral problems." There was no patient with "saliva aspiration" or "food aspiration" (Table 2). The number of swallows for CUP30 was 4.2 ± 1.6 times (Mean ± SD).

Laryngeal penetration was observed in 73 patients for LQ10, 62 patients for MX, and 97 patients for CUP30, indicating that there were significantly more patients with aspiration for CUP30 than for LQ10 ($p < 0.001$) and MX ($p < 0.001$) (Table 3). Aspiration was observed in eight patients for LQ10, 14 patients for MX, and 20 patients for CUP30, indicating that CUP30 had significantly more instances of aspiration than LQ10 ($p = 0.009$) (Table 4). The values of IR were greater than 0.5 between LQ10 and MX for laryngeal penetration and between MX and CUP30 as well as between LQ10 and MX for aspiration (Table 5).

In addition, the correlation coefficients for the P-A

Table 2. Patient characteristics (n = 136).

Etiology, *n* (%)	
Stroke	75 (55.2)
Respiratory disease	16 (11.8)
Neuromuscular disease	13 (9.6)
Esophageal cancer	6 (4.4)
Head and neck cancer	4 (2.9)
Others	22 (16.1)
Dysphagia severity scale (DSS), *n* (%)	
7 within normal limits	7 (5.1)
6 minimum problems	50 (36.8)
5 oral problems	12 (8.8)
4 occasional aspiration	56 (41.2)
3 water aspiration	11 (8.1)
2 food aspiration	0 (0)
1 saliva aspiration	0 (0)

Table 3. 2×2 contingency tables to determine the risk of laryngeal penetration.

$p<0.001$*

		LQ10 +	LQ10 −	Total
CUP30	+	66	31	97
	−	7	32	39
Total		73	63	136

$p<0.001$*

		MX +	MX −	Total
CUP30	+	54	43	97
	−	8	31	39
Total		62	74	136

$p=0.145$

		MX +	MX −	Total
LQ10	+	44	29	73
	−	18	45	63
Total		62	74	136

+, presence of laryngeal penetration; −, absence of laryngeal penetration.
LQ10, 10 mL of liquid; CUP30, 30 g of liquid from a cup; MX, mix of 5 mL of liquid and 4 g of corned beef.

Table 4. 2×2 contingency tables to determine the risk of aspiration.

$p=0.009$*

		LQ10 +	LQ10 −	Total
CUP30	+	5	15	20
	−	3	113	116
Total		8	128	136

$p=0.327$

		MX +	MX −	Total
CUP30	+	4	16	20
	−	10	106	116
Total		14	122	136

$p=0.264$

		MX +	MX −	Total
LQ10	+	1	7	8
	−	13	115	128
Total		14	122	136

+, presence of aspiration; −, absence of aspiration.
LQ10, 10 mL of liquid; CUP30, 30 g of liquid from a cup; MX, mix of 5 mL of liquid and 4 g of corned beef.

Table 5. Inconsistency rate in bolus.

	Inconsistency rate (IR)	
	Laryngeal penetration	Aspiration
LQ10−CUP30	0.23	0.20
MX−CUP30	0.19	0.63
LQ10−MX	0.62	0.54

LQ10, 10 mL of liquid; CUP30, 30 g of liquid from a cup; MX, mix of 5 mL of liquid and 4 g of corned beef.

Scale for each bolus were ρ = 0.370 for LQ10 and CUP30 (p < 0.001, 95% CI: 0.201–0.533), ρ = 0.100 for MX and CUP30 (p = 0.312, 95% CI: −0.107−0.274), and ρ = −0.202 for MX and LQ10 (p = 0.055, 95% CI: −0.362−0.039) (Fig. 1).

Discussion

The present results indicate that laryngeal penetration occurred most commonly, in descending order, for CUP30, LQ10, and MX and that aspiration occurred most commonly, in descending order, for CUP30, MX, and LQ10. However, the investigation of IR values showed that there were high values for LQ10 and MX (laryngeal penetration) and for MX and CUP30 as well as LQ10 and MX (aspiration), suggesting that it was difficult to determine the ranking of difficulty. Investigation of the P-A Scale for the boluses showed a significant correlation between LQ10 and CUP30; however, there was no statistically significant correlation between MX and CUP30 or between MX and LQ10.

There was a higher prevalence of laryngeal penetration and aspiration for CUP30 than LQ10, and it is thought that the size of the bolus has a major effect on this outcome, consistent with the findings of previous studies [12, 13]. The P-A Scale for LQ10 and CUP30 showed a significant correlation, and the IR results for both, in terms of laryngeal penetration and aspiration, were low. Thus, it is possible to predict that cases having laryngeal penetration and aspiration during discrete swallowing of LQ10 will experience laryngeal penetration and aspiration, respectively, during sequential swallowing of CUP30. Although the types of swallowing are different, the difference in the size of the boluses seems to be the major factor that determined the degree of difficulty.

The frequency of laryngeal penetration was lower with MX than LQ10 and CUP30; further, with MX, aspiration occurred more frequently than with LQ10 but less frequently than with CUP30. The IR results showed high values between LQ10 and MX (laryngeal penetration) and between LQ10 and MX as well as MX and CUP30 (aspiration). Therefore, a bolus that causes laryngeal penetration with LQ10 does not always cause laryngeal penetration with MX, and we cannot predict whether a bolus that causes aspiration with LQ10 and CUP30 will cause aspiration with MX. The fact that the P-A Scale did not show a significant correlation between LQ10 and MX or between MX and CUP30 emphasized that the chew-swallowing of MX has a different mechanism of swallowing from discrete swallowing of LQ10 or sequential swallowing of CUP30; thus, we believe it is important to test MX regardless of the results obtained from LQ10 and CUP30 in swallowing examinations. Stage transition duration (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

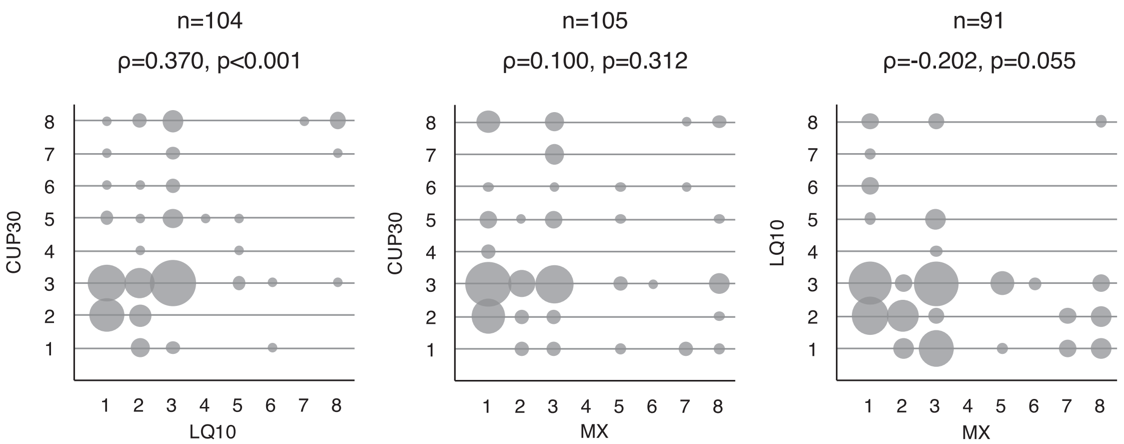

Figure 1. Scatter plot of P-A scale for each bolus.
P-A Scale 1 (no laryngeal penetration, no aspiration) from each bolus was excluded. The correlation coefficients for the P-A Scale for each bolus were ρ = 0.370 for LQ10 and CUP30 (p < 0.001, 95% CI: 0.201−0.533), ρ = 0.100 for MX and CUP30 (p = 0.312, 95% CI: −0.107−0.274), and ρ = −0.202 for MX and LQ10 (p = 0.055, 95% CI: −0.362−0.039).
LQ10, 10 mL of liquid; CUP30, 30 g of liquid from a cup; MX, mixture of 5 mL of liquid and 4 g of corned beef.

of the hyoid is initiated. A delay in STD increases the aspiration risk during discrete swallowing of liquids following stroke [14, 15]. It has also been reported that a delay in STD during chew-swallowing a mixture of solid and liquid food does not increase the aspiration risk [9]. Thus, it is believed that the mechanisms and timings involved in the triggering of the swallowing reflex when swallowing liquids and mixed foods are independent of each other [16].

The present study indicates that when laryngeal penetration or aspiration is observed during swallowing of LQ10 in actual clinical settings, it is highly likely that laryngeal penetration or aspiration will occur during sequential swallowing of CUP30 which involves a larger amount to be swallowed. However, it is difficult to predict whether laryngeal penetration or aspiration will occur with MX based on the LQ10 and CUP30 testing; further, it is difficult to predict whether laryngeal penetration or aspiration will occur with LQ10 or CUP30 based on the results of MX testing; therefore, we believe that both tests should be performed.

This study has certain limitations. It was a retrospective study that investigated only one institution and assessed only the presence or absence of laryngeal penetration and aspiration. There were a small number of patients with severe dysphagia. In a past study that examined the difficulty of test meals in VF, laryngeal penetration and aspiration were more likely to occur with LQ10 and MX than with discrete swallowing of 4 mL of pudding-thick liquid, chew-swallowing of 8 g of corned beef, or discrete swallowing of 4 mL of liquid [2]. We did not attempt to have the patients swallow the three types of boluses for those patients with severe dysphagia since the aspiration risk would have been high.

Conclusions

We compared discrete swallowing, sequential swallowing, and chew-swallowing regarding the risks of laryngeal penetration and aspiration. The frequency of laryngeal penetration was highest for CUP30, followed by that for LQ10 and MX; the frequency of aspiration was highest for CUP30, followed by that for MX and LQ10. It was possible to predict that patients for whom laryngeal penetration or aspiration occurred during discrete swallowing of liquids were likely to experience laryngeal penetration or aspiration when performing sequential swallowing of liquids. However, during chew-swallowing, it was difficult to predict laryngeal penetration or aspiration based on the results obtained under discrete swallowing and sequential swallowing.

References

1. Daggett A, Logemann J, Rademaker A, Pauloski B. Laryngeal penetration during deglutition in normal subjects of various ages. Dysphagia 2006; 21: 270−4.
2. Ozaki K, Kagaya H, Yokoyama M, Saitoh E, Okada S, González-Fernández M, et al. The risk of penetration or aspiration during videofluoroscopic examination of swallowing varies depending on food types. Tohoku J Exp Med 2010; 220: 41−6.
3. Kuhlemeier KV, Palmer JB, Rosenberg D. Effect of liquid bolus consistency and delivery method on aspiration and pharyngeal retention in dysphagia patients. Dysphagia 2001; 16: 119−22.
4. Daniels SK, Foundas AL. Swallowing physiology of sequential straw drinking. Dysphagia 2001; 16: 176−82.
5. Murguia M, Corey DM, Daniels SK. Comparison of sequential swallowing in patients with acute stroke and healthy adults. Arch Phys Med Rehabil 2009; 90: 1860−5.
6. Rosenbek JC, Robbins JA, Roecker EB, Coyle JL, Wood JL. A Penetration-Aspiration scale. Dysphagia 1996; 11: 93−8.
7. Palmer JB, Rudin NJ, Lara G, Crompton AW. Coordination of mastication and swallowing. Dysphagia 1992; 7:187−200.
8. Hiiemae KM, Palmer JB. Food transport and bolus formation during complete feeding sequences on foods of different initial consistency. Dysphagia 1999; 14: 31−42.
9. Kagaya H, Saitoh E, Shibata S, Onogi K, Aoyagi Y, Inamoto Y, et al. Delayed pharyngeal response in chew-swallow does not increase risk of aspiration in individuals with stroke. J Am Geriatr Soc 2015; 63: 1698−9.
10. Saitoh E, Shibata S, Matsuo K, Baba M, Fujii W, Palmer JB. Chewing and food consistency: Effects on bolus transport and swallow initiation. Dysphagia 2007; 22: 100−7.
11. Baba M, Saitoh E. Indication of dysphagia rehabilitation. Rinsho Reha 2000; 9: 857−63. Japanese.
12. McCullough GH, Rosenbek JC, Wertz RT, Suiter D, McCoy SC. Defining swallowing function by age: promises and pitfalls of pigeonholing. Top Geriatr Rehabil 2007; 23: 290−307.
13. Clavé P, de Kraa M, Arreola V, Girvent M, Farré R, Palomera E, et al. The effect of bolus viscosity on swallowing function in neurogenic dysphagia. Aliment Pharmacol Ther 2006; 24: 1385−94.
14. Oommen ER, Kim Y, McCullough G. Stage transition and laryngeal closure in poststroke patients with dysphagia. Dysphagia 2011; 26: 318−23.
15. Kim Y, McCullough GH. Stage transition duration in patients poststroke. Dysphagia 2007; 22: 299−305.
16. Kagaya H, Saitoh E, Yokoyama M, Shibata S, Aoyagi Y, Kanamori D, et al. Initiation of pharyngeal response during discrete swallowing and chew-swallowing in healthy subjects. Prog Rehabil Med 2016; 1: 20160002.