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Mechanisms Involved in Postdeglutition Retention in the Elderly

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Abstract. This study examines possible quantifiable causes of postdeglutition pharyngeal retention in the elderly. Manofluorography and computer processing of video images are performed. Retention in the valleculae and in the piriform sinuses is associated with a markedly reduced pharyngeal shortening, a low tongue driving force (TDF), and a diminished amplitude of the pharyngeal contraction. There is no relationship with the hypopharyngeal suction pump (HSP). Retention limited to the valleculae is associated with a low TDF, and retention restricted to the piriform sinuses is accompanied by a reduced pharyngeal shortening.

Key words: Pharyngeal retention — Pharyngeal shortening — Tongue driving force — Hypopharyngeal suction pump — Pharyngeal contraction — Deglutition —Deglutition disorders.

Deglutition in the elderly is accompanied by a number of qualitative changes which by themselves do not cause aspiration but are likely to put the elderly in an unfavorable position [1,2]. A study by Cook et al. [3] showed that although pharyngeal clearance is nearly complete in young asymptomatic subjects, this is not true in asymptomatic (nondysphagic) elderly. In the aged, mean age 68 years, pharyngeal residuals (the pharyngeal region of interest covered the valleculae as well as the piriform sinuses) ranged widely from 1 to 13%.

The aim of this study was to look at quantitative differences in the oropharyngeal phase of swallowing between swallows with and without retention in the pharynx. In the concept expressed by McConnel [4], the tongue driving force (TDF) and the hypopharyngeal suction pump (HSP) are important in the establishment of a pressure gradient. Therefore, it might be hypothesized that retention develops when these driving forces become deficient. On the other hand, the propagated pharyngeal contraction may facilitate pharyngeal clearance as it seems to follow the bolus tail [5,6]. In addition, a pharyngeal shortening most pronounced between the arytenoids and the valleculae has been observed during deglutition [6,7]. This shortening approximates the tongue base and the upper esophageal sphincter (UES) and could play an important role in preventing postdeglutition retention.

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Materials and Methods

A group of 25 nondysphagic elderly subjects were examined (mean age 80 yr, SD 7 yrs, 14 females, 11 males). They were not taking any drugs that might influence swallowing and had no medical conditions (e.g., stroke, Parkinson's disease) that could interfere with deglutition. Three swallows with a 10 cc bolus of liquid barium (Micropaque® Barii Sulfas Guerbet, Laboratoires Guerbet, Aulnay-Sous-Bois, France) were evaluated in every subject. The viscosity of this bolus was measured by a Rheomat 115 viscometer. The Bingham viscosity was 0.22 PA sec. There was at least 1 min between each swallow. The bolus was administered by syringe and the subjects were asked to swallow it all at one time on our command.

A group of 18 young volunteers served as controls (mean age 29 yr, SD 8 yr, 9 females, 9 males). Manofluorography of these swallows was performed; the images were taken in profile with the head remaining in a neutral position. This technique allows observation on a single videoscreen not only of bolus transport and anatomic events but also of manometric tracings at different heights in the pharynx along with timing numbers. It also permits quantification of the swallowing act by measuring different parameters; in this study, attention was focused on the TDF and the HSP. These parameters are calculated using specifically designed software and in accordance with the guidelines expressed by McConnel et al. [4,8], Mendelsohn and McConnel [9], and Cerenko et al. [10].

The TDF is a measure of the pressure produced by the tongue and applied directly to the bolus in the orpharynx. It is the integral of the area of pressure measured during the time of bolus transit at the first microtransducer. The HSP is a negative (subatmospheric) pressure measured during swallowing at the level of the upper esophageal

sphincter. It is the integral of the surface between the negative pressure wave pattern and the atmosphere pressure baseline.

A manometric probe (outer diameter 5 mm) with five strain gauge microtransducers (Gaeltec Limited, Dunvegan, Isle of Skye, Scotland) 1 mm in length, all oriented in the same radial direction, was passed transnasally. All microtransducers were placed just in the middle of a radiopaque marker which was 1 cm long. The fourth sensor was initially located in the high pressure zone at the level of the peak resting pressure; the first, second, fourth, and fifth sensors were positioned at 4-cm intervals, corresponding to the tongue base, the entrance of the larynx, the UES, and the cervical esophagus, respectively. The third microtransducer, situated 1.5 cm proximal to the fourth, provided additional information on the high pressure zone. All the microtransducers were positioned with the sensor oriented posteriorly (Fig. 1). The output of the different transducers was directly displayed on a TV screen and a Siemens-Elema polygraph, and recorded on a tape for subsequent computer analysis.

Videofluoroscopic studies were obtained in the lateral plane and displayed on a TV screen together with the pressure curves. The fluorographic images and the manometric data were recorded on a VHS video cassette recorder together with a time display for later slow motion and frame by frame analysis. The video images of deglutition were used to evaluate the eventual presence of retention in the different pharyngeal regions. Retention was treated as a dichotomous variable and rated as present or absent. All the swallows were distributed into four categories:

1. No retention: no barium remaining in the valleculae and in the piriform sinuses with the exception of minimal coating of our probe
2. Retention in the valleculae: barium remaining in one or both of the vallecular spaces after the swallow
3. Retention in the piriform sinuses: barium remaining in one or both of the piriform sinuses after the swallow.
4. Diffuse pharyngeal retention which is defined as retention in the valleculae and in the piriform sinuses

Reliability tests on the item of retention resulted in a 100% level of agreement. A 2-dimensional image permits a qualitative estimate of residual bolus in the pharynx after the swallow. No attempt was made to differentiate between degrees of postdeglutition retention.

The peak amplitudes of the pharyngeal contractions were measured on the manometric tracings generated by the second microtransducer; these were recorded on a Siemens-Elema polygraph. Pharyngeal shortening was evaluated by measuring the distance between the most cranial point of the arytenoids and the deepest point of the vallecular space using a Targa video computer-card and Jandel Video Analysis System (Java Jandel Scientific, Corte Madera, CA) software [11]. This is a multipurpose image analysis system with several capabilities, one of which is to measure distances. The setting used in this study permitted freezing the desired video images and measuring the distance between the valleculae and the arytenoids. This was performed in the resting position and at the moment the bolus entered the UES. The top of the tracheal air column was taken as reference to indicate the beginning of the UES. Contrast enhancement was possible and correction for the enlargement factor was performed using the manometric sensors. Reliability when repeating the same measurements proved to be acceptable (difference < 1 mm); this agrees with the observations of Crary et al. [11].

To compensate for the different lengths among the volunteers, the use of relative values was preferred. Therefore, the percentage of shortening relative to the initial distance was determined, and with this value all subsequent calculations were made. Logistic regression analysis and *t*-tests were judged to be appropriate for the statistical analysis.

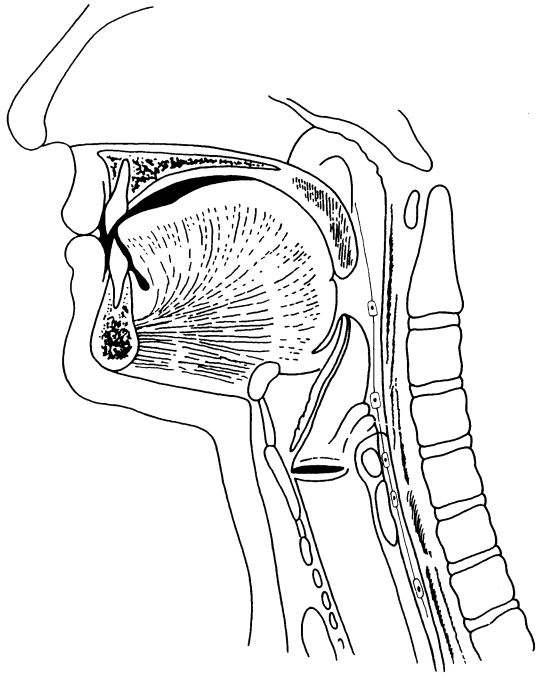

Fig. 1. The figure illustrates the location of the different microtransducers.

Logistic regression was used to identify which independent variables were the strongest predictors of postdeglutition retention.

Results

In the elderly there were 24 swallows with diffuse pharyngeal retention, 23 with no retention at all, 15 with retention only in the vallecular region, and 13 with retention limited to the piriform sinuses. The same pattern nearly always returned in the three swallows performed by each volunteer. No retention was observed in the young control group.

Diffuse Pharyngeal Retention

A comparison was made between retention in both regions and no retention at all (Table 1). There was a significantly higher TDF (difference 0.85 mmHg sec, $p = 4.06 \times 10^{-4}$) and amplitude of the pharyngeal contraction (difference 26 mmHg, $p = 3.16 \times 10^{-4}$) when there was no retention. A significantly reduced pharyngeal shortening was found in the swallows with diffuse pharyngeal retention (difference 16%, $p = 3.53 \times 10^{-7}$). No relation between retention and the HSP could be observed.

A logistic regression analysis was performed. Pharyngeal shortening proved to be the only significant factor involved. Using just this parameter to predict the

Table 1. Diffuse pharyngeal retention in nondysphagic elderly (mean ± SD)

	Diffuse pharyngeal retention	No retention	p^a	Young adults	p^b
TDF (mmHg sec)	1.33 ± 0.71	2.18 ± 0.82	4.06×10^{-4}	1.94 ± 1.12	NS
HSP (mmHg sec)	−1.83 ± 1.75	−1.27 ± 1.06	NS	−2.03 ± 1.60	0.04
Amplitude of the pharyngeal contraction (mmHg)	119 ± 26	145 ± 20	3.16×10^{-4}	124 ± 27	1.41×10^{-3}
Pharyngeal shortening (% of the initial distance)	15 ± 10	31 ± 8	3.53×10^{-7}	31 ± 10	NS

[a]Diffuse retention compared with no retention.
[b]Young adults compared with elderly without retention.

occurrence of diffuse pharyngeal retention permits a correct prediction in 80.9% of the cases. It has a sensitivity of 79.2% and a specificity of 82.6%.

Retention Restricted to Valleculae or Recessus Piriformes (Table 2)

When retention is only present at the vallecular level, the only parameter that differed significantly from the group without retention was the TDF (difference 0.86 mmHg sec, $p = 1.45 \times 10^{-3}$). Those swallows with retention limited to the piriform sinuses showed a significantly lower pharyngeal shortening (difference 10%, $p = 1.31 \times 10^{-3}$).

Comparison with a Young Adult Control Group (Table 1)

In this group no postdeglutition retention was observed. The elderly nonretention subjects had values similar to the young adults as far as the TDF and the pharyngeal shortening were concerned. The amplitude of the pharyngeal contraction was higher in the elderly whereas, as we had already observed in the past [2], the HSP was significantly lower in the elderly.

Initial Length of the Pharyngeal Region of Interest

The initial distance between the valleculae and the arytenoids in the young volunteer group was 19.8 mm (SD 3.0 mm), whereas this same distance proved to be 20.0 mm (SD 6.0 mm) in the elderly. The swallows with diffuse pharyngeal retention were characterized by a similar initial distance, as found in the other groups.

Discussion

Defining normal values for swallowing in the elderly is difficult because physiological aging induces changes in some but not all parameters [1,2,12,13] and because of considerable variation in normal swallowing already present in young adults [14]. In addition, normal aging has to be distinguished from pathological changes. In a radiological study on 6 nondysphagic subjects (aged 60–79 yr) Tracy et al. [15] found postswallow residue to be limited to coating of the tongue base and the valleculae. Several studies [1,3] suggest that pharyngeal retention is often observed in nondysphagic elderly who are not aware of this pharyngeal pooling [1,3]. Cook et al. [3] demonstrated that age had no effect on significant residual counts up to 40 yr but has an increasing effect after 55 yr of age. Radiological investigation allows a qualitative estimate of residual bolus and no attempt was made to differentiate between grades of coating or pooling. Our observations suggest that limited retention in the valleculae and/or in the piriform sinuses should be considered normal in the very elderly and is not accompanied by aspiration.

The mechanisms responsible for the development of pharyngeal retention in asymptomatic elderly are not well known. Different parameters may be involved. We focused our attention on the TDF, HSP, amplitude of the pharyngeal contraction, and the pharyngeal shortening. The first two are the so-called driving forces in the concept proposed by McConnel [4]; the amplitude is a parameter for the strength of the pharyngeal contraction and the pharyngeal shortening, as already observed by Kahrilas et al. [6] and Cook et al. [7], may also be important for minimizing pharyngeal residue.

When diffuse pharyngeal retention is present, an inadequate pharyngeal shortening is the most important factor. Although significantly different between the retention and the nonretention groups, other predictor variables (TDF and the amplitude of the pharyngeal contraction) are not significant in a logistic regression model.

The TDF plays a major role in avoiding retention at the vallecular level and this finding is consistent with the common observation that patients with hypoglossal paresis or tongue resection frequently have residue in the

Table 2. Retention limited to the valleculae or to the piriform sinuses (mean ± SD)

	No retention	Retention limited to the valleculae	p^a	Retention limited to the piriform sinuses	p^b
TDF (mmHg sec)	2.18 ± 0.82	1.32 ± 0.63	1.45×10^{-3}	1.95 ± 0.60	NS
HSP (mmHg sec)	−1.27 ± 1.06	−1.41 ± 0.63	NS	−1.12 ± 0.65	NS
Amplitude of the pharyngeal contraction (mmHg)	145 ± 20	133 ± 19	NS	137 ± 19	NS
Pharyngeal shortening (% of the initial distance)	31 ± 8	35 ± 7	NS	21 ± 9	1.31×10^{-3}

[a]Retention in valleculae compared with no retention.
[b]Retention in piriform sinuses compared with no retention.

valleculae and that squeezing the tongue very hard on swallowing diminishes this residue. When shortening only becomes deficient, retention may be limited to the piriform sinuses; when both shortening and TDF fail, diffuse pharyngeal retention may be the result.

The amplitude and duration of the subatmospheric pressure (HSP) preceding the UES opening was not related to the presence of residue. This is logical because subatmospheric pressure is present only for a short time and disappears when the bolus enters the UES. It may play a role in the propulsion of the bolus tip but has no influence on the bolus tail and thus not on the development of postdeglutition retention.

The role of the pharyngeal contraction in a horizontal plane remains a controversial issue. The exact clinical significance of the most obvious feature of this contraction, namely, the value of the peak amplitude, is still unclear. Swallows without retention in the elderly group had a significantly higher peak amplitude compared with swallows with diffuse pharyngeal retention and with swallows in young adults. Shaker et al. [16] found significantly higher peak amplitudes in the elderly compared with young adults. They speculated [16,17] that the higher amplitudes compensate for the reduced cross-sectional area of the deglutitive UES opening in the elderly [18]. The results obtained from this study would then suggest that failure of this compensatory rise augments the risk for retention, but overlap renders interpretation hazardous.

When asymptomatic elderly without retention are compared with young adults, similar values are obtained with the exception of the amplitude of the pharyngeal contraction and the HSP. The latter parameter was significantly lower in the elderly, confirming earlier reports [2,18] and indicating a reduced compliance of the UES in the elderly. The initial distance between the valleculae and the arytenoids was not different between the two age groups, nor was it related to the eventual presence of postdeglutition retention. We could not confirm the lower position of the larynx with advancing age as was previously reported [12] but our study was not longitudinal. In addition, body height is considerably larger in young people which may lead to a ''longer pharynx'' in this age group. The concept of pharyngeal shortening is relatively new and is largely attributed to stylopharyngeal muscle contraction stylopharyngeal muscle contraction [6].

Kahrilas et al. [6] reported that the distance between the valleculae and the arytenoids reaches a minimum at the opening of the UES. Therefore, we also measured this distance on the first frame showing opening of the UES. The top of the tracheal air column was used as reference point for the UES. The peak UES pressure is found at a level 1.5 cm below the top of the tracheal air column [7,19,20] but the UES extends over 3–4 cm and a clear reproducible moment is required to freeze the image for measurements.

The exact moment of the maximal shortening may also be up for discussion. As already stated, Kahrilas et al. [6] found a clear relation between this event and the opening of the UES. The study was performed in a young adult sample (23–32 yr old). There is evidence for a delayed triggering of the swallow reflex in the elderly compared with young adults [13,15]. This dissociation between the oral and pharyngeal stage may lead to a delayed shortening in the elderly. Digitalization of the entire swallowing sequence would be required to establish the exact relationship in the elderly.

Finally, the indicators used in this study reflect movement of the anterior pharyngeal wall but similar movement of the posterior wall was demonstrated by Palmer et al. [21].

Conclusion

Retention in asymptomatic elderly is influenced by different quantitative parameters. A low tongue force increases the likelihood of vallecular retention after deglutition, thus reinforcing the concept that effortful swallowing (i.e., tongue squeezing) drastically reduces retention in the valleculae.

For retention in the piriform sinuses, a diminished shortening of the pharynx is involved. Pharyngeal shortening is also the main factor when diffuse pharyngeal retention occurs. These studies have to be confirmed but the present data already offer new insights into the processes that lead to retention and provide a rationale for the development of treatment strategies.

References

1. Ekberg O, Feinberg M: Altered swallowing function in elderly patients without dysphagia: radiologic findings in 56 cases. *AJR 156:*1181–1184, 1991
2. Dejaeger E, Pelemans W, Bibau G, Ponette E: Manofluorographic analysis of swallowing in the elderly. *Dysphagia 9:*156–161, 1994
3. Cook IJ, Weltman MD, Wallace K, Shaw DW, McKay E, Smart RC, Butler SP: Influence of ageing on oral-pharyngeal bolus transit and clearance during swallowing: scintigraphic study. *Am J Physiol 266:*G972–G977, 1994
4. McConnel F: Analysis of pressure generation and bolus transit during pharyngeal swallowing. *Laryngoscope 98:*71–78, 1988
5. McConnel F, Cerenko D, Jackson R, Guffin T: Timing of major events of pharyngeal swallowing. *Arch Otolaryngol Head Neck Surg 114:*1413–1418, 1988
6. Kahrilas P, Logemann J, Lin S, Ergun G: Pharyngeal clearance during swallowing: a combined manometric and videofluoroscopic study. *Gastroenterology 103:*128–136, 1992
7. Cook I, Dodds W, Dantas R, Massey B, Kern M, Brasseur J, Hogan W: Opening mechanisms of the human upper esophageal sphincter. *Am J Physiol 257:* G748–G759, 1989
8. McConnel F, Cerenko D, Hersh T, Weil L: Evaluation of pharyngeal dysphagia with manofluorography. *Dysphagia 2:*187–195, 1988
9. Mendelsohn M, McConnel F: Function in the pharyngoesophageal segment. *Laryngoscope 97:*483–489, 1987
10. Cerenko D, McConnel F, Jackson R: Quantitative assessment of pharyngeal driving forces. *Otolaryngol Head Neck Surg 100:*57–63, 1989
11. Crary M, Butler M, Baldwin B: Objective distance measurements from videofluorographic swallow studies using computer interactive analysis: a technical note. *Dysphagia 9:*116–119, 1994
12. Logemann JA: Effects of aging on the swallowing mechanism. *Otolaryngol Clin N Am 23:*1045–1055, 1990
13. Robbins JA, Hamilton JW, Lof GL, Kempster B: Oropharyngeal swallowing in normal adults of different ages. *Gastroenterology 103:*823–829, 1992
14. Ekberg O, Nylander G: Cineradiography of the pharyngeal stage of deglutition in 150 individuals without dysphagia. *Br J Radiol 55:*253–257, 1982
15. Tracy JF, Logemann JA, Kahrilas PJ, Jacob P, Kobara M, Krugler C: Preliminary observations on the effects of age on oropharyngeal deglutition. *Dysphagia 4:*90–94, 1989
16. Shaker R, Ren J, Podvrsan B, Dodds WJ, Hogan WJ, Kern M, Hoffmann R, Hintz J: Effect of aging and bolus variables on pharyngeal and upper esophageal sphincter motor function. *Am J Physiol 264* (*Gastrointest Liver Physiol 27*):G427–G432, 1993
17. Shaker R, Lang IM: Effect of aging on the deglutitive oral, pharyngeal, and esophageal motor function. *Dysphagia 9:*221–228, 1994
18. Shaw DW, Cook IJ, Dent J, Simula ME, Panagopoulos V, Gabb M, Shearman DJ: Age influences oropharyngeal and upper esophageal sphincter function during swallowing. *Gastroenterology 98*(*5*):A390, 1990
19. Kahrilas PJ, Dodds W, Dent J, Logemann JA, Shaker R: Upper esophageal sphincter function during deglutition. *Gastroenterology 95:*52–62, 1988
20. Nilsson ME, Isberg A, Schiratzki H: The location of the upper oesophageal sphincter and its behaviour during bolus propagation—a simultaneous cineradiographic and manometric investigation. *Clin Otolaryngol 14:*61–65, 1989
21. Palmer JB, Tanaka E, Siebens AA: Motions of the posterior pharyngeal wall in swallowing. *Laryngoscope 98:*414–417, 1988