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Dysphagia

Durational Aspects of the Oral-Pharyngeal Phase of Swallow in Normal Adults

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Abstract. We present durational data on normal oral-pharyngeal swallows in adults obtained using ultrasound imaging. The effects of normal aging on the oral-pharyngeal phase of swallowing were studied in 47 healthy adults. Timing of the oral-pharyngeal phase of swallow was determined from frame-by-frame analysis of ultrasound videos of the motion of the tongue and hyoid bone from initial rest to final resting position. Duration of unstimulated (dry) swallows was compared to stimulated (wet) swallows across four age groups and by sex and age. For most subjects, dry swallows were longer than wet swallows; moreover, swallow duration was longest for older women than any other group. As age increased (55+), oral swallows were accompanied by extralingual gestures. Ability to produce a timed series of continuously dry swallows was somewhat influenced by age. Findings are suggestive of an age change more typical in women, with a pattern of multiple lingual gestures commonly seen after age 55 in both sexes. We suggest that subtle, subclinical, oral neuromotor changes occur with normal aging to cause these findings.

Key words: Swallowing, duration – Aging – Tongue and hyoid motion – Ultrasound.

Complaints of swallowing disorders are typically considered to be associated with older people, particularly men over age 60 [1, 2]. It is unclear whether such problems are normative, age-related perturbations in physiology or whether they reflect diseases or iatrogenic causes (e.g., medications, surgical procedures) that occur with increased frequency in older people. Some evidence supports the latter conclusion [3–6], but in general there are few specific studies of swallowing across the adult life span. Since mealtime remains the primary focus of social and interpersonal activity for many elderly people, disordered swallowing would have a negative impact on their health, nutritional status, and quality of life.

The majority of studies on swallowing in the elderly have been of abnormal persons, usually by chart review, clinical observation, or from interview and/or questionnaire alone. There are few quantitative data from direct in vivo examination of the oral mechanism. Most studies on normal swallow have used radiation or invasive procedures, making it difficult to examine routinely noncomplaining elderly persons.

In this paper we will briefly review the potentially multiple causes of dysphagia in the elderly and then present our findings, which are based on ultrasound study of the oral-pharyngeal phase of swallowing in nondiseased adults of various ages. Since we will not attempt to discuss the esophageal phase of swallowing, the reader is referred to previous work on this subject [2, 3, 7–11].

Material provided here will be placed in the context of both the oral and the pharyngeal phases. The oral phase of swallow is initiated when the tongue propels a bolus posteriorly by squeezing against the hard palate just anterior to the faucial area, which activates the swallow reflex [12]. At the moment the swallowing reflex is initiated, the pharyngeal phase begins as the bolus penetrates the faucial isthmus and the hyoid bone moves abruptly forward and upward toward the mandible, thus elevating the epiglottis and larynx to protect the airway. The distance between the hyoid

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and mandible is reduced and the base of the tongue is pulled anterior and superior in the oral cavity [13, 14]. The hyoid, base of the tongue, and larynx then descend and retract to return to their initial resting position at the termination of the pharyngeal swallow [15–17]. This is usually a rapid, single-motion sequence and demarcates the entire oral-pharyngeal phase of swallow. Recently Ekberg [16] described the elevation of the hyoid as a "two-step movement" with a pause between the first and the second movements. He described the first movement as posterior and cranial followed by an anterior motion. The motion of the hyoid directly affects the closure of the airway since it determines epiglottic movement. Furthermore, the motions of the hyoid from rest and back to rest demarcate the entire oropharyngeal swallow, ending as the bolus passes into the esophagus [16].

Our early ultrasound research, on eight young adults aged 19–26 [18], indicated that this sequence occurred within a range of 1.13–2.02 s (mean $\pm$ SEM 1.54 ± 0.3). In a later study these results were compared to a population of 15 older adults [19]. Since differences in duration were found between younger and older adults, these findings needed to be explored in more detail. We therefore studied the initiation and termination of hyoid bone activity in defining the oral-pharyngeal phase of swallow.

Literature Review

General Neuromuscular Function

Considerable evidence suggests that with increased age, marked structural and biochemical alteration occurs in neural and muscle tissue [20–24]. In addition, many reports exist of altered neurophysiological response [25, 26] and altered muscular activity [27–29]. Such findings point to some level of defect in motor activity as implicit in normal aging motor systems. What is not clear is how widespread this is, and whether it affects motor function at a clinical or more subtle research level, in the non-diseased elderly. However, any consideration of normal swallowing function or dysfunction must rest on this premise of change.

Causes of Neuromuscular Dysfunction: Diseases and Medication

A plethora of conditions that are more common in elderly persons affect the neuromuscular components involved in swallowing. These include specific syndromes or diseases such as Parkinson's disease, Steele Richardson's disease, Shy-Drager's syndrome, amyotrophic lateral sclerosis, Huntington's disease, multiple sclerosis, myasthenia gravis, as well as generally debilitating conditions such as stroke, cerebellar pontine lesions, and diabetic neuropathy [30, 31]. Indeed, it has been suggested that dysphagia associated with neurologic disease usually will affect the oral and pharyngeal rather than esophageal phases of swallowing [32, 33]. Because these conditions produce paralysis, motor weakness, dyscoordination, and diminution of vegetative oral-motor functioning, it is clear that motor control of swallowing will be affected [26, 34]. Besides pathologic influences on motor function, medication is likely to have considerable influence on motor performance in the orofacial region. Many drugs are known to induce oral dyskinesia [35]. Any agent that affects neurotransmitter metabolism or release could certainly lead to compromised deglutition and must be a consideration in aging individuals, among whom use of medication is markedly higher than in other age segments of the general population [36].

With advanced age, a preexisting neuromuscular condition or disease may worsen and may necessitate placement of the patient in an institution. Although at any one time only about 5% of elderly persons are patients in such facilities, these individuals commonly present with swallowing disorders [37]. Besides chronic neurologic disease and effects of medication, it is important to recogize the significance of head or trunk positioning in causing impaired swallow [38]. Malpositioning of the body has been found to impair alimentation, fluid intake, and ability to ingest medication in institutionalized elderly persons [39, 40]. Also, some elderly individuals are unable to swallow food or secretions because of dementia paired with a neuromuscular dysfunction [38].

Alterations in Oral Physiology and Oral Tissues

Consideration of all oral physiological functions is relevant to any discussion of deglutition and particularly with respect to aging. All oral tissues and structures participate in preparing a bolus for swallowing and are thus critical. The dynamic forces and interactions among the orofacial neuromusculature, teeth, mucosa, sensory innervation, and salivary secretions theoretically should influence the ability of the individual to swallow competently. While it is not our purpose to discuss oral health and functional status during aging in detail, a brief summary of relevant considerations is germane.

Several reports suggest that alterations occur in oral motor function with increased age [19, 41]. Most such information pertains to diminished masticatory muscle performance, even among generally healthy persons [6, 42–44]. In addition, Baum and Bodner [6] reported decreased postural functions of the circumoral muscles during aging as well as a perturbation in tongue postural function in older aged men. Both Heath [45] and Feldman et al. [44] report an increase in swallowing threshold; older subjects take more time, and more strokes, to prepare food to a consistency they consider swallowable. Although it has been suggested that increased tooth loss, at present more common but diminishing in older persons, negatively affects swallowing ability, studies by Chauncey et al. [46] argue against such a conclusion. In fact, Price and Darvell [47] propose that edentulous persons use the tongue as a major force of mastication in the oral preparatory phase of swallowing and report that this lingual activity increases with age. Another common generalization associated with aging is decreased saliva production, which could markedly affect bolus formation and translocation. Recent studies support the thesis of no general diminution in salivary gland function with increased age. Rather it appears that most previous age-related complaints of decreased saliva resulted from disease or pharmacologic therapy [48–52]. There is very limited information on oral sensory function in different aged persons. Best studied is gustatory function and this shows no significant decrement in performance with age [53]. Finally, it should be noted that obstructive lesions and benign and malignant tumors occur more frequently in older persons and may affect swallowing and food ingestion [10, 54–56].

Summary of Studies in Progress

The preceding review indicates that normal aging has generally minor effects on the swallowing process and that major alterations are more typically the result of pathologic change. Conclusions about deglutition and aging are drawn from results based primarily on "clinical ratings" rather than direct evaluation of swallowing. Such studies have until now required the use of x-radiation and ingestion of radiopaque material; they posed some danger or discomfort to subjects. Furthermore, the oral-pharyngeal phase of swallowing has historically been given minor attention in "traditional" studies of swallowing in the upper and lower gastrointestinal tract using x-ray procedures. However, by modifying the x-ray procedure and varying the amount and type of radiopaque material, Logemann [12] and Robbins et al. [33] have been able to study oral and pharyngeal aspects in some detail. This procedure still requires radiation exposure and does not allow detailed visualization of the interactive motions of the hyoid and the soft tissues of the tongue. Recent advances in the development of real-time ultrasound oral imaging [18, 57, 58] have provided a noninvasive, safe diagnostic technique that circumvents these disadvantages and allows one to conduct studies directly on swallowing in different aged adults. The current study was designed to create a reliable data base describing the effects of normal aging on the duration of the oral and pharyngeal phases of swallow in different aged persons. Specifically, the duration of the swallow, from initiation to termination of tongue/hyoid activity (i.e., from oral phase to entry of bolus into esophagus), was investigated with ultrasound imaging.

Materials and Methods

The study population consisted of 47 healthy, community-dwelling subjects ages 18–75 (25 women, $\bar{x} = 60.0 \pm 4.5$ years; 22 men, $\bar{x} = 59.9 \pm 5.5$ years). All were middle-class, white patients who were free of any medical complaints and were not taking medications other than vitamins. The elderly subjects were recruited from the National Institutes of Health (NIH) normal volunteer population or were NIH employees and their relatives. All subjects had functional natural dentition; none had any removable dental appliances. For study purposes, subjects were grouped into three age categories (18–34, n = 15; 35–54, n = 13; 55–75, n = 19) as shown in Table 1. All subjects completed a questionnaire about swallowing and were given a thorough oral-motor and speech evaluation prior to examination of their swallowing.

Oral Motor Function Evaluation

An oral motor evaluation scale was developed to rate subjects' performance in 10 areas: anatomy of oral structures, oral-facial symmetry, tongue and lip strength, physiology of oral motor-facial function, swallowing, oral sensation, voice, articulation, speech fluency, and oral diadochokinesis [59, 60]. This is a cranial-nerve-based procedure and includes aspects of accepted speech and oral motor examination [35, 61]. Ratings of 1 (normal), 2 (mild deficit), 3 (moderate), and 4 (severe) were given in each of these 10 subcategories based upon performance on a standard oral-motor evaluation. Ratings were then averaged into three major categories: anatomy, physiology, and speech. All subjects included in the normal sample had overall ratings in the three major categories of less than 1.75.

Swallowing Screening

A self-administered questionnaire on swallowing consisting of items in checklist format was given to each subject (Appendix A). The questions covered conditions, complaints, diseases, and medications commonly associated with dysphagia. No subject was included if any items checked indicated that swallowing or food intake was altered in any way.

Table 1. Distribution of normal subjects (n = 47)

Age (yrs)	Sex		
	Men (n = 22)	Women (n = 25)	Total
18–24	3	4	7
25–34	4	4	8
35–44	3	4	7
45–54	3	3	6
55–64	6	8	14
65–74	3	2	5

Ultrasound Examination

All scanning was performed with an Advanced Technologies Laboratories mechanical sectoring real-time ultrasound scanning unit. Both a 3 MHz and a 5 MHz transducer were used with an 85° sector and a frame rate of 30 frames/s [18, 19, 57, 58]. Adjustments in time gain compensation and system gain were made by image inspection.

All scans were recorded simultaneously on a 3/4 inch Sony U Matic videotape cassette recorder with a video timer recording to hundreths of a second. Alphanumeric characters, timing, and an averaged acoustic signal were added to the video display to help in locating specific frames of interest from a Sony 10 s video disc that interfaced with a Micro Sonics CAD 88 computer-assisted diagnosis system.

Subjects were seated in a dental chair with a headrest to stabilize anterior/posterior head motion. Lateral motions of the head were regulated by the examiner, who stood behind the subject holding the transducer stable with a forefinger placed at the temporomandibular joint and thumb below the chin. The transducer was positioned submentally until the hyoid shadow appeared at approximately 22° in the left upper quadrant of the scan relative to the midline sector marker displayed permanently on the screen. By using this same criterion to reference hyoid position for all subjects, a resting position was obtained at the start of each swallow. All scanning was performed at midline sagittal position with the transducer angled 15°–20° posteriorly to view the hyoid or 15°–20° anteriorly to image the body of the tongue and a water bolus.

A depth setting of 5 was used with the 5 MHz transducer to image a smaller area and obtain a more detailed view of the hyoid bone and posterior tongue. All measurements of hyoid motion during swallowing were made at this setting. A depth setting of 9 was used with the 3 MHz transducer to allow for a more expanded view of the tongue/hyoid region posteriorly and tongue anatomy and bolus position anteriorly (Fig. 1). In one case the depth was set at 7 to accommodate an unusually large oral cavity.

Subjects were scanned with the 5 MHz transducer at rest and were instructed to breathe normally without excessive inspiration to inhibit unnecessary excursions of the larynx that could affect hyoid position. They performed three single dry swallows, with no added fluid in the mouth, followed by 10 s of continuous dry swallowing. Next, water was placed in the mouth for wet swallow studies. To prevent any motion of the head that could alter the transducer/hyoid placement, all water for wet swallows was injected slowly into the mouth with a syringe. A 20 ml bolus of water was injected first to delineate the palate and other dimensions in the oral cavity (Fig. 2). Subjects held the bolus for 5–10 s before being directed to "swallow." Then a series of three 10 ml bolus swallows were completed, with patients instructed to hold the bolus at the front of the mouth before swallowing.

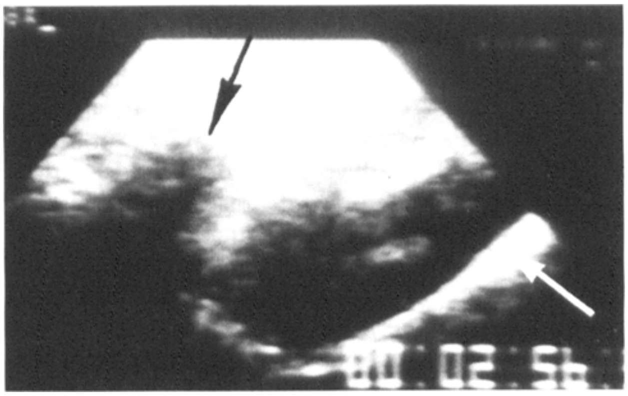


Fig. 1. Midline sagittal scan of tongue at rest prior to swallow. Anterior of tongue near tip and tongue surface are seen at *white arrow*. The hyoid bone casts a triangular acoustic shadow (*black arrow*).

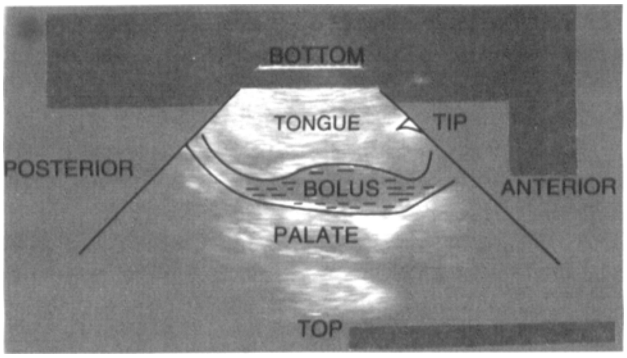


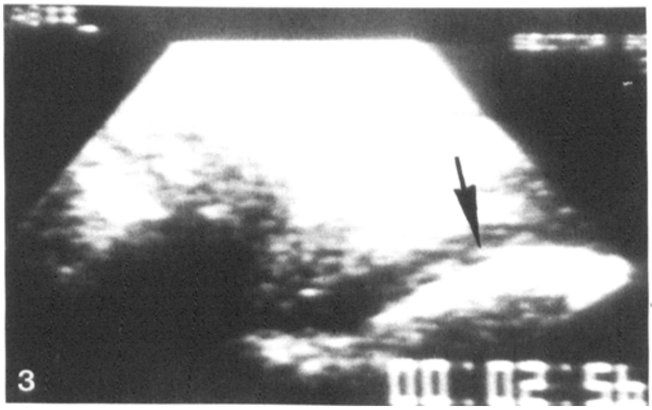
Fig. 2. Midline sagittal scan with water bolus shows displacement of tongue surface and palate.

Data Analysis

Durational measurements of each swallow were made from a frame-by-frame analysis of the videos using a 10 s Sony video disc. The duration of both dry and wet swallows was measured from the frame at which the hyoid bone first moved anteriorly and superiorly from rest to the frame when it returned to the stable resting position.

The motion of the hyoid bone was classified into four distinct phases and each phase was measured: (1) from rest to maximum anterior displacement (RM) (Figs. 3, 4); (2) for the time that the hyoid remained steady at maximum anterior displacement (aM); (3) time from maximum anterior displacement back to resting position (MR) at the completion of the oral phase of swallowing; and (4) total time (T). Swallows were compared in relation to order of sequence (first vs. second vs. third) and duration of each hyoid phase in both dry and wet swallows. The number of dry swallows in 10 s was calculated by viewing the 10-s segments in real time.

In the initial phase of the study, interjudge reliability was assessed by having three judges measure duration of each phase of hyoid motion (RM, aM, MR) five times each for each of the three swallows selected randomly from three subjects. These measures were made with alphanumeric codes and timing sequences shielded from view. The standard deviation in measurement was less than 0.06 s among judges and less than 0.04 s in the single judgements.



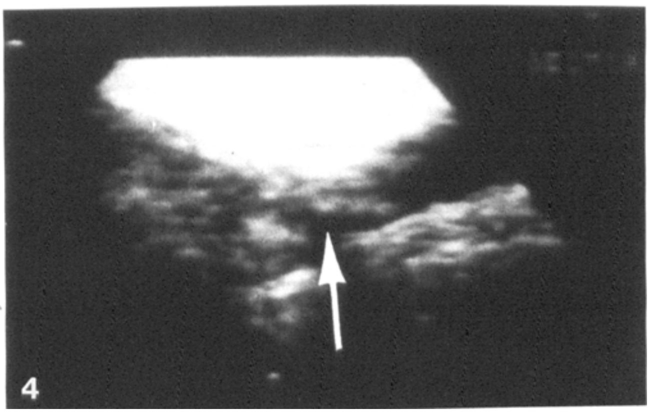


Fig. 3. Midline scan shows tongue curving to initiate swallow reflex and transport bolus posteriorly as hyoid begins its forward motion.

Fig. 4. Focused scan (5 MHz transducer, depth setting 5 cm) shows hyoid motion (*white arrow*) at its maximum anterior displacement before returning to rest position.

Table 2. Duration (s) of phases of hyoid motion from initiation to completion of swallow for 47 normal adults (mean ± SD)

Group (yr/sex)	Rest–maximum anterior displacement (RM)		Time at maximum position (aM)		Maximum position return to rest (MR)		Total time of swallow (T)	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
18–34 W (n = 8)	1.17 ± 0.76	0.59 ± 0.20	0.19 ± 0.05	0.21 ± 0.07	0.42 ± 0.10	0.51 ± 0.16	1.79 ± 0.75	1.30 ± 0.30
18–34 M (n = 7)	1.38 ± 0.78	0.62 ± 0.16	0.16 ± 0.06	0.19 ± 0.09	0.46 ± 0.18	0.54 ± 0.18	2.00 ± 0.85	1.39 ± 0.21
35–54 W (n = 7)	1.82 ± 1.42	0.68 ± 0.29	0.17 ± 0.01	0.18 ± 0.08	0.50 ± 0.17	0.44 ± 0.12	2.47 ± 1.37	1.42 ± 0.47
35–54 M (n = 6)	1.61 ± 0.74	0.93 ± 0.33	0.20 ± 0.09	0.18 ± 0.07	0.47 ± 0.18	0.38 ± 0.11	2.78 ± 0.81	1.49 ± 0.39
55–74 W (n = 10)	1.95 ± 1.31	1.24 ± 0.70	0.17 ± 0.16	0.26 ± 0.42	1.29 ± 0.94	1.11 ± 0.82	3.41 ± 1.38	2.43 ± 1.05
55–74 M (n = 9)	1.18 ± 0.57	1.08 ± 0.84	0.10 ± 0.09	0.23 ± 0.48	1.31 ± 1.18	1.44 ± 0.82	2.58 ± 1.50	2.47 ± 1.00

Comparisons (Wilcoxon) were made of the duration and order of each component of the swallow described above to determine if swallow duration differed during dry or wet swallows. Based on the Wilcoxon comparisons, dry swallow 1 and dry swallows 2 and 3 were grouped separately for analysis of duration of RM and T. The duration of the four components of the wet and dry swallows (RM, aM, MR, T) was compared between age groups, within a sex, and between sexes, within an age group, using an unpaired t-test. Finally, Welch's solutions to the Behrens-Fisher problem were used to compare the number of dry swallows made in 10 s between age groups, within a sex, and sexes, within an age group. When comparing between sexes, a two-sided t-test was used, and when comparing among ages, a one-sided t-test was used because of the assumption that age would increase swallowing duration. The number of extra hyoid gestures needed to complete a swallow was tabulated for the older subjects.

Results

Our primary finding was that the older subjects' swallows were generally slower than those of the younger subjects, regardless of whether a bolus of water or the saliva within the mouth was used as a stimulant. The averages and standard deviations of each phase of hyoid motion in the series of three dry and three wet swallows are presented in Table 2. Results in Table 2 suggest that total time (T) for dry swallows is generally longer than for wet swallows and that duration of both dry and wet swallows increases with age. Further analysis of the entire data sample comparing dry and wet swallows revealed that durational differences because the second and third dry swallows were longer in time (T) than the first dry swallow ($p<0.001$). In all but two comparisons this difference reflected an increase in the RM phase of the second and third swallow as the hyoid moved from rest to maximum anterior displacement. No significant differences were found for any group during the aM phase for either the dry or wet conditions. When dry swallows were compared to wet swallows, the findings were similar: the second and third dry swallows were significantly longer (T) than the wet swallows ($p=0.0212$). This difference was also due primarily to the RM phase.

When these differences were evaluated accord-

Table 3. Significant comparisons of duration of three phases of wet and dry swallows between age groups within sex

Age group	Phases		Total time
	RM	MR	
Wet swallows			
18–34 vs. 55–74	Women[a]	Men[a]	Women, men[a]
18–34 vs. 35–54	Men[a]	ns	ns
35–54 vs. 55–74	ns	Men[a]	Women, men[a]
Dry swallows			
18–34 vs. 55–74	ns	Women[a]	Women[a]
35–54 vs. 55–74	ns	Women[a]	ns

Times were always faster for younger age group.
[a] $p \geq 0.02$.
[b] Time at maximum anterior position (aM) was not significant in any comparison.

ing to subjects' sex and age (Table 3), several patterns emerged. We will discuss the findings among women first. Significant differences were found between the youngest and oldest women for wet swallows in RM ($p=0.013$) and T ($p=0.006$). Differences were also found for wet swallows (T), when middle-aged women were compared to the older women ($p=0.02$). The dry swallows of the older women were considerably longer (T) than those of the younger women ($p=0.005$) and this difference was greatest during the MR phase ($p=0.011$). Although the dry swallows of the older women were not longer in T than those of the middle-aged women, the MR phase was significantly longer ($p=0.02$).

The pattern for men was markedly different. No differences were found for dry swallows. For wet swallows the pattern was more like that found for women: older men also took longer to execute the swallow (T) than either younger ($p=0.006$) or middle-aged ($p=0.02$) men. The men differed from the women, however, in that these differences were found in the MR phase ($p=0.005$). Although there was no difference in T between the young and middle-aged men, the RM phase was longer ($p=0.02$). In summary, the younger subjects tended to swallow more quickly than the older subjects.

Multiple Gestures

Figure 5 shows data on the percentage of different subjects who presented with multiple gestures of the hyoid during swallowing. These data are displayed in 10-year age spans, except for the youngest group, rather than in 20-year age spans as previously used. These 10-year groupings indicate better any subtle age-related differences. As can be seen, there is only one subject under age 54 with multiple hyoid gestures. In contrast, 64% of those 55–64 years old (9 of 14) and 80% of those 65–75 years old (4 of 5) were found to have multiple hyoid gestures. These double or triple motions were only seen in the RM or MR phase of the swallow, which phases may account for the durational differences described above.

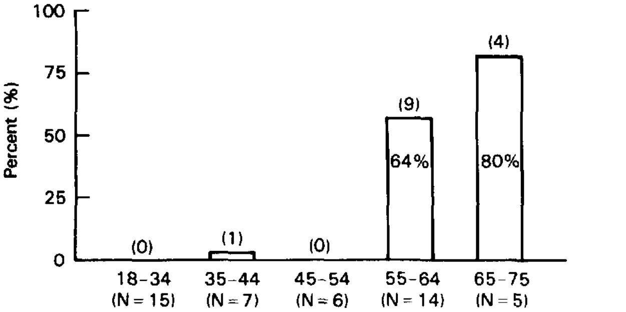


Fig. 5. Percentage of normal subjects according to age demonstrating multiple gestures of hyoid during swallowing.

Table 4. Means and standard deviations for number of dry swallows in 10 s significant comparisons between age groups and sexes

Age			Combined mean
18–34	35–54	55–75	
Men			
3.14±1.57 (n=7)	2.83±1.15 (n=6)	3.13±0.97 (1)[a] (n=9)	3.03 (n=22)
Women			
2.87±0.42 (2)[a] (n=8)	2.42±1.48 (n=7)	1.89±1.00 (3)[a] (n=10)	2.39 (n=25)

[a] p=0.01, (1) vs (3), (2) vs (3).

Number of Dry Swallows in 10 s

The means and standard deviations of the number of dry swallows completed in 10 s are shown in Table 4. Men were able to produce slightly more than three complete swallows in 10 s, with some completing as many as five swallows. On the other hand, women produced an average of less than 2.4 swallows in 10 s, with younger women completing nearly three and older women averaging less than two. Significant differences in the number of dry swallows in 10 s were found between the older men and older women ($p=0.0352$) and between the younger and older women (p=0.0177).

Discussion and Conclusion

This study was designed to determine whether age affects the oral and pharyngeal phases of swallowing. Other investigations of hyoid activity and timing of normal swallowing that have used fluoroscopic techniques have not focused on effects of age and sex [15, 16]. Although differences exist between the procedures and structures best visualized from these radiographic studies and ultrasonic studies of swallowing, the findings from each technique are comparable. For example, the two-step hyoid movement and pause noted by Ekberg corresponds to our RM, with the time at aM being the pause. The depression and posterior motion of the hyoid are the MR. Similarly, Curtis et al. found a total swallow time of 1.5 s by using the motionless larynx, which corresponds well with the total wet swallow times that we found (Table 2). Since we were looking at effects of age and did not average across all subjects, it appears that our timing data are directly comparable.

Using ultrasound to image the tongue/hyoid motions, we were able to detect several age-related changes in the timing and motion patterns of the initial oral voluntary phase and pharyngeal phase on both wet and dry swallows. Though durational differences were found in three of four distinct phases of hyoid bone movements, the normal subjects we studied had no complaints of swallowing impairment and did not aspirate or choke during the study. The duration of the oral phase of swallowing tended to increase with age among normal healthy individuals, in agreement with our earlier, more limited, findings [19]. Along with suggesting a possible explanation for this change, this section will review our findings.

The normal elderly adults in our sample were significantly different from the normal younger adults in the total time needed to complete a dry or wet swallow. Some additional support for this finding exists in an earlier manometric study [62], which showed that mean swallowing duration increased significantly with age. Although this was true for both men and women, it was more pronounced in the older women. The increased duration of swallow occurred primarily in the RM phase. The swallow reflex is initiated here, moving the hyoid bone forward toward the mandible, as the larynx elevates to protect the airway when the bolus moves into the pharynx. When the airway was protected during the aM phase, there were no age-related differences in swallowing. Since the airway was protected, no laryngeal penetration, aspiration, or choking occurred and, despite generalized slowing of the preceding oral preparatory events, elderly subjects apparently perceived their swallows as normal. We thus offer a possible explanation for the absence of reported complaints of swallowing difficulty in older persons. Our older subjects apparently equated abnormal swallowing with gagging or choking and were unaware that they were producing repeated lingual gestures. As long as the airway was protected, and the bolus transported into the pharynx, swallowing was believed to be intact.

Since the initial dry swallow was faster than subsequent dry swallows, we suggest that some increased muscular effort was needed to initiate a series of swallows. In addition to increased effort as a cause for slowed repeated swallows, repeated swallowing would reduce the amount of natural oral lubrication that serves as a stimulus to swallow [63]. This combination of factors would require more effort from the tongue and oral muscles to produce the swallow reflex and move the hyoid forward as the tongue moved. Attempts to generate saliva could lengthen the time needed to execute the second and third dry swallows. This observation agrees with the results by Mansson and Sandberg [62, 63], who found that successive dry swallows became more difficult because of lessened salivary secretion, thereby reducing the sensory stimulation needed to elict the swallow reflex. In a similar fashion, Hughes et al. [64], using ultrasound imaging, found that salivary hypofunction markedly increased the duration of swallowing for both dry and wet swallows. Indeed, we found that these increases in duration of total swallow time were generally associated with extra hyoid gestures in the RM phase. Thus, there is some reason to believe that these durational differences were caused by a combination of increased muscular effort, probably related to reduced saliva and sensory stimulation.

These differences do not indicate pathologic changes or disorder, but appear to be caused by the entire complex of oral-motor alterations and decrements that occur in normal persons after age 55 and are generally exacerbated after age 75. These findings could relate to the previously cited research on motor performance in aging and point to a generalized slowing of the initiation of action, with delays in temporal patterns, probably attributable to subtle changes in the neurologic substrates needed for any muscular series of events [26].

Typical findings among our older subjects were extra hyoid gestures and more time needed to move the hyoid to its anterior position. These gestures, when reviewed by other investigators, are often described as tongue pumping or rocking. Whereas only one middle-aged person and no younger persons in our sample made extra hyoid/tongue rocking motions, 64–80% of the older subjects did. Some evidence suggests that lingual pumping behaviors may reflect neurologic change. For example, when Robbins et al. [33] and Veis and Logemann [65] studied swallowing in normal and neurologically impaired subjects, they found that only the impaired subjects produced more than one tongue-pumping motion during a single swallow. Because the differences in the duration of swallow found in our older sample were caused by the RM phases, the phase requiring initiation of motion, we suggest that subtle neuromotor or neurologic changes could be responsible for increasing the duration of swallowing in the older group. An additional explanation may be that the hyoid and base of the tongue may be less firmly supported by the geniohyoid and mylohyoid muscles that elevate them during swallow. This provides some objective confirmation of Baum and Bodner's [6] clinical observations of increased dysfunction of tongue suspensory muscles in healthy normal adults. Although our present sample was larger than that in many previous studies, an even larger data base from normal subjects is needed to ensure that these findings can be generalized. Because our normal subjects were either self-selected or volunteers, this sample may not be totally representative of the larger population. Also, since we found that normal aging affected the duration of swallow, and suggested that there might be an underlying neurologic basis for this finding, the added effect of a frank neurologic condition must be studied in the future.

It is interesting to note that most of the subjects in our older sample did not complain of being slow eaters or having difficulty swallowing. Thus, any alterations detected by us in the healthy elderly are accepted as normal by them and must be considered as such, whether or not sophisticated diagnostic procedures can be used to detect them. Nonetheless, this study provides us with a method for studying the oral-pharyngeal phases of swallowing noninvasively and has given us a basis for further comparisons of disordered elderly subjects with neurologic, neuromotor, dental, or salivary gland dysfunction.

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Appendix A

Swallowing Questionaire

Name: Age:
Date: Sex:

Check the statements that describe you:

1. ______ difficulty swallowing
2. ______ pain while swallowing
3. ______ "lump" in throat
4. ______ can't chew hard food
5. ______ can't chew fibrous or "crunchy" foods
6. ______ avoid foods like apples, nuts, and cookies

7. ______ avoid foods like celery
8. ______ food spreads all over mouth while eating
9. ______ food gets caught in cheek and is not swallowed
10. ______ food falls out of mouth before swallowing
11. ______ excessive saliva or mucus in mouth
12. ______ very dry mouth
13. ______ food comes out of mouth or nose while swallowing
14. ______ cough or choke before, during, or after swallowing
15. ______ food gets caught at base of tongue, high in throat
16. ______ food gets caught lower in throat
17. ______ slow eater
18. ______ food or water comes into mouth without vomiting, often while lying down
19. ______ more difficulty swallowing liquids than solids
20. ______ more difficulty swallowing solids than liquids

Do you have:

1. ______ poorly fitting dentures
2. ______ dry mouth (xerostomia)
3. ______ frequent heartburn or indigestion
4. ______ hoarseness after swallowing
5. ______ decreased oral sensation
6. ______ paralysis of oral or facial muscles
7. ______ frequent pneumonia or respiratory problems

Have you been told you have:

1. ______ dysphagia
2. ______ hiatal hernia
3. ______ gastric or peptic ulcer
4. ______ thyroid disorder
5. ______ amyotrophic ateral sclerosis (ALS)
6. ______ multiple sclerosis (MS)
7. ______ Parkinson's disease
8. ______ muscular dystrophy
9. ______ dystonia
10. ______ myasthenia gravis
11. ______ dermatomyositis
12. ______ scleroderma
13. ______ rheumatoid arthritis
14. ______ cerebral palsy
15. ______ poliomyelitis
16. ______ dysautonomia
17. ______ Raynaud's phenomenon (hands or feet turn red or blue)
18. ______ schizophrenia or other psychiatric disorder
19. ______ stroke
20. ______ cancer of the lips, mouth, throat, larynx, or neck
21. ______ structural abnormality of the face or mouth
22. ______ cleft lip/palate
23. ______ polymyositis
24. ______ diabetes

Have you ever had:

1. ______ surgery or radiation to the thyroid
2. ______ surgery or radiation of the face, head, neck, or mouth
3. ______ head trauma
4. ______ brain surgery
5. ______ cardiac surgery
6. ______ high blood pressure

Have you taken or do you take:

1. ______ tranquilizers
2. ______ antacids
3. ______ cancer drugs
4. ______ ulcer drugs
5. ______ heart medications
6. ______ insulin

List all other medications you presently take (other than vitamins)

Food Preference/History:

Foods you avoid:

Foods you prefer: