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By

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ABSTRACT

THE EFFECTS OF AGING ON SELECTED PARAMETERS OF OROPHARYNGEAL SWALLOWING

By

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To understand the normal swallow process across the adult life span, this cross-sectional descriptive research was designed to identify and quantify systematic differences in oropharyngeal swallowing physiology among normal nondysphagic older adults. The aging characteristics of deglutition were systematically quantified to determine the extent to which gradual morphological and physiological changes in the upper aerodigestive tract predicted deviations in oropharyngeal swallowing.

This study consisted of 30 adult men, divided into three age groups (50-55, 60-65, 70-75). The subjects demonstrated normal oropharyngeal swallowing history as determined by completion of a health history questionnaire which ruled out the presence of dysphagia and medical conditions associated with dysphagia. Completion of a dysphagia screening further ruled out the presence of swallowing difficulty.

Subjects participated in a videofluoroscopic swallow study designed to measure five oropharyngeal swallowing duration measures: oral transit duration, pharyngeal transit duration, total oropharyngeal swallowing duration, stage transition duration, and hyo-laryngeal response duration. Two additional measures were obtained: oral bolus position and stage transition pattern.

Subjects completed three swallows of liquid barium (5 cc) and three swallows of a barium-paste-coated cookie. Analysis of variance revealed no significant differences among age groups in temporo-spatial duration measures for both liquid and barium-paste-coated cookie swallows.

Chi-square analysis revealed a significant difference between the youngest and oldest group in oral bolus position for liquids before initiation of the swallow, but not for solid swallows. Significant differences were found between the youngest group and the two older groups in stage transition pattern for both liquids and solids. Subjects in the younger group were more likely to demonstrate a continuous pattern of bolus flow between the oral and pharyngeal stages of swallowing. Subjects in the two older groups were more likely to demonstrate an interrupted pattern of bolus flow between stages. Both intrajudge and interjudge reliability exceeded 90%.

It appears that the swallow is a relatively stable and highly synchronous process in adult men between ages 50 and 75; a continuum of decline in oropharyngeal swallow function does not appear to be the standard in the group of healthy, nondysphagic adult men sampled in this study.

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CHAPTER I

INTRODUCTION

Normal Swallowing

In normal swallowing, oral intake of liquids and solids--necessary to sustain human life--is accomplished through a precisely timed, highly coordinated physiologic process that enables liquids and solids to pass without incident from the oral cavity to the stomach (Dodds, 1989; Miller, 1986). Researchers have studied normal swallowing events in adults in order to better understand the intricate neuromuscular control that allows for successful and uneventful swallowing physiology (Logemann, 1988).

Quantitative measurement of normal oropharyngeal swallowing events allows for detailed knowledge of anatomical, neuroanatomical, and physiological events. A variety of swallowing events have been studied: bolus clearance (Cook et al., 1994), effects of bolus temperature (Bisch, Logemann, Rademaker, Kahrilas, & Lazarus, 1994; Ren et al., 1993), impact of bolus volume on swallowing (Bisch et al., 1994; Lazarus et al., 1993; Ren et al., 1993; Tracy et al., 1989), pharyngoesophageal pressure (Fulp et al., 1990; Wilson, Pryde, Macintyre, Maran, & Heading, 1990), sequences of movement in the oropharyngeal swallow (Hrycyshyn & Basmajian, 1972; Shawker et al., 1983; Stone & Shawker, 1986), swallow safety (Langmore et al., 1988; Langmore, Schatz, & Olson, 1991), oropharyngeal swallowing efficiency (Rademaker, Pauloski, Logemann, & Shanahan, 1994), oropharyngeal residue (Hamlet et al., 1996), and timing and duration of oropharyngeal swallowing events (Borgstrom & Ekberg, 1988; Cook et al., 1989; Curtis, Cruess, Dachman, & Maso, 1984; Shawker, Sonies, Hall, & Baum, 1984; Sonies, Parent, Morrish, & Baum, 1988).

Measurement of Swallowing

The normal swallow process has been studied by means of ultrasonography (Shawker, Sonies, & Stone, 1984; Shawker, Sonies, Stone, & Baum, 1983), manometry (Fulp, Dalton, Castell, & Castell, 1990; Mendelsohn & McConnel, 1987), electromyography (Basmajian & Dutta, 1961; Doty & Bosma, 1956; Elidan, Chochina, Gonen, & Gay, 1990), scintigraphy (Cook et al., 1994; Hamlet et al., 1996; Muz, Mathog, Miller, Rosen, & Borrero, 1987; Silver, VanNostrand, Kuhlemeier, & Siebens, 1991), and endoscopy (Bastian, 1991; Langmore, Schatz, & Olson, 1988). Manometry has been combined with electromyography, fluoroscopy, endoscopy, and other imaging techniques to quantify temporal relationships among oropharyngeal swallowing (Dejaeger, Pelemans, Bibau, & Ponette, 1994; Shaker, Dodds, Dantas, Hogan, & Arndorfer, 1990).

Videofluoroscopy is a widely used research, diagnostic, and clinical tool for quantifying normal and disordered swallowing (Dodds, Logemann, & Stewart, 1990; Dodds, Stewart, & Logemann, 1990; Donner, 1986; Ekberg & Feinberg, 1991; Elliott, 1988; Logemann, 1993). This radiographic assessment tool defines structural and physiological components of the oral, pharyngeal, and esophageal stages of swallowing; evaluates timing and movement patterns; and identifies type and nature of swallowing difficulty. Videofluoroscopy allows for assessment of the critical physiologic elements of the oropharyngeal swallow (Langmore & Logemann, 1991): (a) duration of bolus transit, (b) nature and pattern of tongue movement during oral transit, (c) range of tongue base retraction, (d) timing and onset of the pharyngeal swallow response, (e) range of pharyngeal wall contraction, (f) timing and duration of laryngeal closure, (g) range of laryngeal excursion, and (h) duration of upper esophageal sphincter (UES) opening.

Swallowing Disorders in the Aging Population

In addition to normal swallowing, researchers have focused on understanding the nature of dysphagia--a difficulty or discomfort in swallowing--which occurs when the process of deglutition is disrupted at any stage (Miller, 1986). Dysphagia is a symptom of one or more underlying pathologies, not a disease in and of itself (Kuhlemeier, 1994).

Dysphagia is a common but often unrecognized symptom of a variety of neurologic, pathologic, and nonpathologic conditions which may be acute or chronic (Sonies, 1987). Oropharyngeal dysphagia has been associated with various degenerative disorders, metabolic diseases, infectious diseases, toxic diseases, cranial nerve neuropathies, autoimmune disorders, and dementing diseases. Two of the three most common medical diagnoses for hospitalized patients with dysphagia (Kuhlemeier, 1994) were diseases of the circulatory system (primarily stroke) and respiratory system (primarily pneumonia).

Dysphagia is frequently associated with older people and the process of aging (Ekberg & Feinberg, 1991; Feinberg & Ekberg, 1991; Sheth & Diner, 1988; Ward et al., 1989). Swallowing difficulty often affects older people as a direct result of disease states that occur with increased frequency in the older population (Baum & Bodner, 1983).

Dysphagia has been well documented in cerebral vascular accident (Horner & Massey, 1988; Johnson, McKenzie, Rosenquist, Lieberman, & Sievers, 1992; Meadows, 1973; Robbins & Levine, 1988; Veis & Logemann, 1985), traumatic brain injury (Lazarus & Logemann, 1987), and Parkinson's disease (Logemann, Blonsky, & Boshes, 1975; Robbins, Logemann, & Kirchner, 1988; Stroudley & Walsh, 1991). Head and neck cancer is a frequent cause of swallowing difficulty among older individuals (Fleming, Weaver, & Brown, 1977; Logemann, 1985; Logemann & Bytell, 1979; McConnel, Mendelsohn, & Logemann, 1986). Feinberg and Ekberg (1991) examined 50 old adults--ranging in age from 79 to 94 years--who were referred for videofluoroscopic swallowing assessment. Etiology of dysphagia was attributed to dementia (42%), stroke (30%), deconditioning (12%), and Parkinson's disease (10%).

According to Sheth and Diner (1988), hypertrophic spurs, osteophytes, rheumatoid arthritis, myasthenia gravis, polymyositis, oculopharyngeal muscular dystrophy, hyperthyroidism, and cricopharyneal indentation all have a negative impact on the integrity and synchrony of the swallow process in the older patient. Structural and motility disorders commonly associated with esophageal dysphagia in older individuals include neoplasm, peptic stricture, diverticula, vascular compression, achalasia, diffuse esophageal spasm, and scleroderma (Ergun & Miskovitz, 1992).

In a study by Bloem et al. (1990), 16% of a group living at home (aged 87 years or more) reported dysphagia symptoms. The prevalence of swallowing complaints in 476 adults from the general population aged 50 to 79 years was investigated by Lindgren and Janzon (1991). The most frequent complaints were gastroesophageal reflux and globus sensation (20%). Other reported complaints were bolus obstruction (3%) and frequent choking during meals (5%).

Tibbling and Gustafsson (1991) examined the presence of dysphagia in a random sample of 796 adults from the ages of 60 to 99. Dysphagia was regarded as present if the subject reported a "feeling of sticking" in the throat (hypopharyngeal) or in the chest (esophageal) when eating. Symptoms of dysphagia were reported by 62 subjects (8%). Hypopharyngeal dysphagia alone (1%) was less frequent than combined hypopharyngeal and esophageal dysphagia (3%). Those with symptoms of hypopharyngeal dysphagia all reported a feeling of anxiety at mealtime, and all preferred not to eat alone.

The institutionalized adult is at increased risk for development of oral feeding and swallowing problems. Those institutionalized are at increased risk for malnutrition, dehydration, and infection because of problems associated with chewing and swallowing. It is not surprising that dysphagia has been found to be prevalent in 59% of nursing home residents (Trupe, Siebens, & Siebens, 1984).

A study of 740 residents in two nursing facilities, mean age 72.9 years, revealed that 31% were on mechanically altered diets (Groher & McKaig, 1995). The most frequent diagnoses included dementia (53%), stroke not producing dementia (26%), and progressive neurological disease (8%). Of those on mechanically altered diets, 87% were at the level of either pureed or tube feeding; choking was the primary reason for the diet modification.

A study focusing on identification of clinical indicators for unintentional weight loss and pressure ulcers (Gilmore, Robinson, Posthauer, & Raymond, 1995) examined 290 older residents living in nursing homes. The authors found that chewing problems accounted for more than half of the clinical indicators. Swallowing problems were indicated in 30% of those residents with a combination of unintentional weight loss and intake less than 50%. In addition, swallowing problems occurred with 47% frequency in residents with unintentional weight loss and pressure ulcers.

In the Feinberg and Ekberg (1991) study of 50 old adults referred for videofluoroscopy, 46% of the subjects were diagnosed with oral stage dysfunction, 34% with combined oral-pharyngeal dysfunction, and 20% with pharyngeal stage dysfunction. In all subjects, oral stage dysfunction was the most common cause of bolus misdirection.

Objective measures of normal swallowing have recently been applied to the study of the effects of aging on normal swallowing physiology (Cook et al., 1994; Ren et al., 1993; Robbins, Hamilton, Lof, & Kempster, 1992; Sonies, Parent, Morrish, & Baum, 1988). According to Robbins et al., the speed of swallowing begins a gradual slowing after age 45. The authors concluded that at 70 years of age, the swallow process is significantly slower in time than in individuals under 45 years of age.

It has been suggested that older adults demonstrate an increase in multiple lingual gestures to complete an oral swallow (Sonies et al., 1988), a different lingual pattern in swallow initiation (Dodds et al., 1989), oral sensorimotor incoordination (Ekberg & Feinberg, 1991), and altered tongue posture and masticatory function (Baum & Bodner, 1983). Findings in studies focusing on age effects have reported longer oral transit durations in older people (Cook et al., 1994; Shaw et al., 1990), increased delay in onset of the pharyngeal swallow (Robbins et al., 1992; Tracy et al., 1989), increased pharyngeal transit durations for liquids (Cook et al., 1994), increased delay in upper esophageal relaxation (Fulp et al., 1990; Robbins et al., 1992; Shaw et al., 1990; Tracy et al., 1989), increased total swallowing time (Robbins et al., 1992; Sonies et al., 1988; Tracy et al., 1989), and increased pharyngeal post-swallow residuals and pharyngeal clearance time (Cook et al., 1994).

Purpose of the Study

It is still not clear how aging affects swallowing in any or all of the three primary systems: afferent system responsible for sensory input, central control system located in the brainstem swallowing centers, or efferent system responsible for motor activation. The question of whether older adults develop compensatory swallowing strategies as a result of normal degeneration of neural and muscular tissue has yet to be answered.

Normal swallowing is essential to the maintenance of healthy states and management of disease in the older population. The normal swallow process in older adults is still relatively poorly understood. Incomplete knowledge of its physiological mechanisms raises problems of definition further complicated by the aging process. Because there are few specific studies of swallowing across the adult life span, researchers remain unclear in their ability to distinguish pathologic from nonpathologic age-related changes in the swallow process.

The aging characteristics of deglutition must be quantified to determine the extent to which gradual morphological and physiological changes in the aerodigestive tract associated with older individuals can predict pathological from nonpathological deviations in oropharyngeal swallowing. Further studies are needed to determine whether aging alters the synchrony, symmetry, and integrity of the oropharyngeal swallowing process.

Researchers have begun to investigate the structure and function of both the oral and pharyngeal stages of the aging swallowing mechanism with increased detail. However, there remains both scientific and clinical need for additional investigations based on the observations that (a) minimal research has focused on oropharyngeal swallowing of solids, (b) discrepancies exist among researchers in reports of age effects in bolus duration measures, (c) no studies have examined the pattern of stage transition between the oral and pharyngeal stages of swallowing in detail, (d) a continuum of decline in oropharyngeal swallowing after age 50 has not been reported, and (e) it is not clear whether the swallowing patterns observed after age 50 represent a natural compensatory mechanism of the aging swallow mechanism.

To further understand the normal swallow process across the adult life span, this cross-sectional descriptive research was designed to identify and quantify the presence or absence of systematic differences in oropharyngeal swallowing physiology among competent, nondysphagic old adults using videofluoroscopy. Specifically, this investigation attempted to examine the continuum of decline reported by Robbins et al. (1992) to determine whether significant differences in age-related swallow function exist in the population of adults over age 50. The following questions were posed:

1. Is there a significant age effect in oral transit duration during the swallow?

2. Is there a significant age effect in pharyngeal transit duration during the swallow?

3. Is there a significant age effect in total oropharyngeal swallowing duration?

4. Is there a significant age effect in stage transition duration during the swallow?

5. Is there a significant age effect in hyo-laryngeal response duration during the swallow?

6. Is there a significant age effect in oral bolus position prior to initiation of the swallow?

7. Is there a significant age effect in the stage transition pattern during the swallow?

CHAPTER II

REVIEW OF THE LITERATURE

Normal Swallowing

Traditionally, the act of swallowing, or deglutition, is described as a highly coordinated process involving four stages: oral preparatory stage, oral stage, pharyngeal stage, and esophageal stage. Although the stages allow for a more organized study of the swallow process, normal swallowing is considered a rapid, dynamic process involving a functionally integrated system (Robbins et al., 1992). Swallowing as a physiological phenomenon is a coordinated sequence of intricate motor and sensory events that may be initiated as a conscious volitional act. However, the majority of swallows occur subconsciously without cerebral involvement.

In adults, saliva production occurs at a rate of approximately 0.5 ml/min, resulting in a swallow rate of one swallow/min in alert states (Dodds, Stewart, & Logemann, 1990). Swallowing and salivation nearly cease during sleep states (Lichter & Muir, 1975). In the normal adult, this equates to approximately 1,000 swallows per day, the majority of which occur involuntarily in response to salivation.

Oral Preparatory Stage

During the oral preparatory stage, the bolus is mixed with saliva, shaped, and positioned on the tongue in a cohesive bolus in preparation for the swallow. It involves voluntary control in the coordination of lip closure, jaw motion, buccal tone, and tongue motion (Logemann, 1988) to collect the bolus.

Chewing involves rotary, lateral motion of the tongue and mandible (Logemann, 1993), motions critical for mixing the bolus with saliva and placing it on the teeth. The oral preparatory and oral stages of swallowing are linked closely together and are, therefore, often difficult to distinguish. Peripheral and central recognition of food in the mouth and motor programming are essential components in initiating the oral swallow.

Oral Stage

In the oral stage of swallowing, the primary action involves propulsion of the bolus from the oral cavity into the oropharynx. Bolus preparation and bolus movement are under voluntary control, yet they are often performed without conscious effort.

The oral stage of swallowing is initiated by the onset of a leading complex of four closely related events (Cook et al., 1989): (a) the onset of tongue tip movement; (b) tongue base movement, (c) vertical hyoid movement, and (d) submental electromyographic activity. Two distinct types of oral stage tongue tip movement initiate the normal liquid swallow (Cook et al., 1989; Dodds et al., 1989). The tipper-type swallow begins with the bolus located on the superior surface of the tongue with the tongue tip pressed against the upper incisors and alveolar ridge. In the dipper-type swallow, the bolus is positioned in front of or inferior to the tongue tip, which is then scooped to a supralingual location. Although type of oral stage tongue-tip movement differs among and within subjects, Dodds et al. concluded that the tipper-type swallow pattern is dominant for all age groups.

Forward and upward phases of tongue blade movement are initially prevalent in the oral stage of the normal swallow (Stone & Shawker, 1986) and are highly synchronous with movement of the hyoid bone, which serves as a supporting structure for the larynx and platform for the tongue. The tongue tip moves forward with the tip and sides making contact with the alveolar ridge, followed by anterior to posterior tongue elevation. Subsequently, the tongue applies pressure to the bolus tail and pushes the bolus posteriorly into the oropharynx in a groove on the lingual dorsum.

Descent of the soft palate and elevation of the tongue dorsum form a linguavelar valve that prevents the bolus from entering the pharynx prematurely. As the tongue propels the bolus posteriorly into the oropharynx, the soft palate then elevates, meeting the upper part of the posterior pharyngeal wall and closing off the nasopharynx.

The mean duration of tongue movement required to swallow a 5 cc water bolus from initiation to termination was reported as 1.54 s (Shawker et al., 1983). Oral transit duration, also referred to as oral transit time, is always under 1.5 s in normal swallowing and is usually less than 1.0 s (Logemann, 1993). Oral transit duration (OTD) is defined as the time it takes the bolus head to begin posterior movement on the tongue, until the bolus head reaches the juxtaposition of the ramus of the mandible and the base of the tongue on videofluoroscopy.

Pharyngeal Stage

The oral and pharyngeal stages of swallowing are closely coupled in the normal swallow. The pharyngeal stage is the third stage in the swallow sequence, involving a series of involuntary, highly coordinated neuromuscular events that occur to draw the pharyngeal wall upward over the bolus and propel the bolus through the hypopharynx for entry into the esophagus.

According to Robbins (1988), the pharyngeal stage is typically initiated as the bolus head reaches the ramus of the mandible at the junction of the tongue base, as observed on videofluoroscopy. Robbins further stated that the pharyngeal stage is governed in its entirety by velopharyngeal, laryngeal, and cricopharyngeal valving action. First, the velopharyngeal valve functions to prevent entrance of material into the nasal cavity. Second, the actions of the laryngeal valve responsible for protection of the airway during the normal swallow include sphincteric closure of the aryepiglottic folds, false vocal folds, and true vocal folds. Third, the cricopharyngeal valve remains in a state of tonic contraction and relaxes to allow bolus transport into the esophagus.

The principal neuromuscular events in the pharyngeal swallow involve velopharyngeal closure, glottic closure, superior/anterior movement of the hyoid and larynx, epiglottic descent, tongue base retraction, pharyngeal contraction, and upper esophageal sphincter (UES) relaxation (Logemann, 1993). Glottic closure appears to be the initial event in the swallow sequence, and coordination of laryngeal kinetics with bolus transport prevents laryngeal penetration from occurring.

Swallow-induced vocal cord adduction, essential to the normal swallow process, precedes the onset of hyo-laryngeal elevation and pharyngeal peristaltic action (Shaker et al., 1990). Adduction of the vocal cords occurs first. In the majority of subjects studied, vocal cord adduction occurred 0.22 s before initiation of laryngeal elevation. Following vocal fold closure, horizontal then vertical approximation of the arytenoids occurs. Anterior tilting and contact of the arytenoid cartilages to the base of the epiglottis is a significant feature in airway closure (Logemann, 1993).

The next principal event in the pharyngeal swallow involves hyoid displacement and laryngeal ascent. In a study involving a single subject swallowing a 5 ml liquid bolus (Logemann, Kahrilas, Begelman, Dodds, & Pauloski, 1989), superior hyoid displacement was approximately 9 mm and anterior displacement was 11 mm. This was similar to the results reported by Jacob, Kahrilas, Logemann, Shah, and Ha (1989). In their study of eight subjects swallowing 1 ml liquid boluses, mean superior hyoid excursion was 8 mm and mean anterior excursion was 11 mm. The entire hyo-laryngeal complex elevated approximately 2 cm in normal subjects (Jacob et al., 1989; Kahrilas, Logemann, Krugler, & Flanagan, 1991).

Following hyo-laryngeal displacement, inferior movement of the epiglottis to horizontal position over the laryngeal aditus is a principal element in airway closure.

This movement is closely correlated with hyoid elevation (Ekberg & Sigurjonsson, 1982). The duration of laryngeal vestibule closure is approximately 0.6 to 0.7 s in normal swallowing.

As the bolus head enters the hypopharynx and the tail approaches the base of the tongue, the contracted lateral and pharyngeal walls meet the base of the tongue, which moves about two-thirds of the distance posteriorly (Kahrilas, Logemann, Lin, & Ergun, 1992). This action creates the major pressure-generating force required to transport the bolus through the hypopharynx (Logemann, 1993). Caudal-to-rostral contraction of the pharyngeal constrictors produces a downward "stripping wave" action of the posterior pharyngeal wall to propel the bolus into the esophagus. The intricate actions involved in pharyngeal transit duration (PTD), also referred to as pharyngeal transit time, normally take place in 0.3 to 1.0 s (Logemann, 1990). Speed of the peristaltic wave in the pharyngeal constrictors is approximately 10.8 cm/s (Baum & Bodner, 1983; Borgstrom & Ekberg, 1988).

As the bolus reaches the contracted pharyngoesophageal segment (PE segment), bolus force contributes to upper esophageal sphincter (UES) opening. Dodds et al. (1990) proposed four essential elements to normal UES opening: (a) relaxation of the contracted UES (0.5 s), (b) low compliance of the relaxed UES, (c) hyoid traction and anterior cricoid cartilage movement on the relaxed UES, and (d) distention of the relaxed UES due to radial pressure forces of the bolus. In normal swallowing, arytenoid contact to base of epiglottis generally occurs within ±0.06 s of

UES opening, with no bolus hesitation in the pyriform sinus prior to opening (Logemann et al., 1992).

Establishment of a pressure gradient for bolus passage contributes to the completion of the pharyngeal stage (McConnel, Cerenko, & Mendelsohn, 1988). Propulsive pressure is generated by the tongue and pharyngeal walls in the oropharynx. Negative pressure generated by the pharyngoesophageal (PE) segment in the hypopharynx establishes the bolus gradient. The pharyngeal stage is completed when the bolus tail flows through the PE segment into the esophagus.

The timing of events in the swallow sequence is directly related to the volume and viscosity of the bolus swallowed. Timing of hyoid movement, laryngeal elevation, upper esophageal sphincter (UES) relaxation, and transsphincteric flow have been reported to be volume dependent (Cook et al., 1989). Increases in bolus volume cause events in the swallow sequence to occur earlier in time. Larger boluses enter the pharynx and arrive at the UES earlier than smaller boluses. Dantas, Dodds, Massey, and Kern (1989) reported significant differences in timing and magnitude of swallowing events which were due to variations in density and viscosity of the barium preparation swallowed. High-density barium resulted in significantly longer oral and pharyngeal transit durations, delayed UES opening, and greater duration of UES opening.

Esophageal Stage

During the final esophageal stage, the bolus is propelled the length of the esophagus into the stomach. The esophageal stage of the swallow involves active peristalsis under involuntary neural control (Logemann, 1988). The esophageal stage involves (a) relaxation of the upper esophageal sphincter (UES) allowing for passage of the bolus into the esophagus, (b) descent of the hyoid bone and larynx to the resting position, (c) cessation of contraction of the posterior pharyngeal wall, (d) opening of the nasopharyngeal passage, and (e) relaxation of the lower esophageal sphincter at the base of the esophagus to allow passage of food into the stomach.

Esophageal transit duration (ETD) is defined as the time it takes the bolus head to travel from the entrance of the upper esophageal sphincter until the tail passes through the lower esophageal sphincter. ETD has been reported to range from 3 to 9 s (Janssens, cited in Miller, 1986) and 8 to 20 s (Mandelstam & Lieber, 1970) in adults.

Neural Control Mechanisms

Two major theories exist that describe the neural control mechanism of the oropharyngeal swallow: reflex chain and central pattern generator hypotheses (Miller, 1982). In the first, a bolus stimulates sensory receptor fields in the oropharynx, an action that sequentially triggers the next step in the swallowing sequence. Swallowing therefore proceeds as a reflex chain, with each step stimulating the next.

In the second hypothesis, Doty (1968) proposed that the central swallowing pathway consisted of a group of interneurons within the central nervous system that controlled a complex motor response, a "central pattern generator." Once the pattern generator was triggered, it would activate motor neurons in a systematic order, with each swallow being a programmed sequence of events governed by the medullary region of the brainstem, independent of sensory feedback.

The primary sensory stimuli for swallowing originate from sensory receptor fields in the oral and pharyngeal cavity. However, the precise nature of the stimuli responsible for eliciting the pharyngeal swallow remains in question. Miller and Sherrington (1916) first recognized that electrical stimulation of regions of the central nervous system including selected areas of the cortex and portions of the brainstem elicited a pharyngeal swallow. Pommerenke (1982) identified the anterior faucial arches as the most sensitive site for eliciting the swallow reflex, followed in sensitivity by the posterior pharynx and pillars. However, Pommerenke concluded that no single area was solely responsible for elicitation of the swallowing reflex.

Doty (1951) stimulated selected patterns of peripheral nerve input with electrical pulses and found that the central swallowing pathway was triggered by these patterns. Doty and Bosma (1956) showed that swallowing was a sequenced pattern of muscle activation involving the tongue, floor of the mouth, pharyngeal constrictors, suprahyoid and infrahyoid muscles, and upper esophageal constrictor. They concluded that the motor response could be preserved in the presence of impaired peripheral feedback.

In a later study, Miller (1982) reported that the faucial pillars, pre-epiglottic sinus, glottis, and base of epiglottis were the sensory receptor regions most successful in eliciting the pharyngeal swallow response. Linden, Tippett, Johnston, Siebens, and French (1989) examined the bolus position at pharyngeal onset and found that a significant proportion of the swallows were elicited after the bolus head passed the faucial pillars. Their summations lent further support to Miller's (1982) conclusion that a broad zone in the pharynx is responsible for elicitation of the pharyngeal swallow.

Two medullary regions exist for the central control of the swallow response (Miller, 1993). The dorsal region consists of areas around the nucleus tractus solitarius and reticular formation. The dorsal region receives the initial peripheral sensory descending cortical inputs that effect the swallowing response. The ventral region, which surrounds the nucleus ambiguus and reticular formation, functions to organize the sequential activation of motor nuclei group and modify the motor output during swallowing. Conceptually, the dorsal region contains "master neurons" that activate the swallowing process, and the ventral region contains "switching neurons" that transmit the timed output to the proper motor neuron pools.

According to Dodds (1989), sensory fields activate the central paired brainstem swallowing centers in the nucleus tractus solitarius and medullary reticular formation in a coded manner. Each swallow center consists of an elaborate array of interneurons that process sensory input, generate a preprogrammed stereotypical swallowing response, and distribute signals to cranial nerve motor nuclei to activate striated muscle peristaltic contraction in the pharyngeal and esophageal stages of swallowing. The swallowing center ensures the accuracy of bilateral motor activity and the proper sequencing of muscular action necessary for swallowing to occur without incident.

In the older adult, swallowing probably depends on stimulation of sensory receptors that in turn modulate the programmed swallowing sequence. Swallowing likely reflects a relatively stable and unvarying sequence of motor activity in the presence of a system that adjusts to widely varying factors (Kennedy & Kent, 1988).

Age-Related Changes

General Characteristics

Aging--the result of complex changes occurring at molecular, cellular, and organ levels--results in a progressive decline in the body's ability to respond to homeostatic equilibrium disruptions (Chodzko-Zajko & Ringel, 1987), thereby producing a functional decline in human performance. The structural and behavioral consequences of aging appear relatively consistent across all physiological systems.

Characteristics of aging include atrophy, dystrophy, and edema--precursors to gross morphological changes such as decreased elasticity and demyelinization (Chodzko-Zajko & Ringel, 1987). From an anatomical and physiological perspective, aging organ systems are usually slower and exhibit decreased strength, stability, coordination, and endurance.

One of the most reliable observations from research on aging is the general slowing of behavior with increased age. As age increases, behavioral speed decreases (Salthouse, 1985). Behavioral slowing of motor responses is characterized by a decline in reaction time, the time necessary for transmission of sensory information, decision making, and motor execution. According to Salthouse, cognitive decline in the normal elderly is associated with decreased psychomotor speed; slowing of central cognitive processes; and decline in somatosensory, auditory, and visual sensory acuity.

Age-dependent alterations in oral morphology (Logemann, 1990) include increased fatty and connective tissue changes in the tongue. The mucosa, bony framework, and salivary glands show gradual but significant changes with age (Heeneman & Brown, 1986), resulting in atrophy of the alveolar margin and reduction in quality and quantity of saliva. Lingual activity plays a major role in oropharyngeal swallowing, and isometric maximum tongue blade pressure has been found to decline with age (Robbins, Levine, Wood, Roecker, & Luschei, 1995).

The most common age-related sensory changes affecting communication in the elderly are perceptual deficits in hearing and vision. The chemical senses--taste, smell, and trigeminal sensation--show age-related changes; however, the character and degree of alteration appear unique to each system (Murphy, 1992). Marked decline in older individuals has been reported in oral form discrimination (Ostreicher & Hawk, 1982) and taste (Moeller, 1989). According to Murphy (1992), flavor preference shifts more in older individuals, who perceive greater concentrations of sugar and salt as more pleasant. Taste sensitivity at threshold and suprathreshold taste intensity perception both decline in aging. However, the magnitude of the decline, the degree to which various taste qualities are affected, and the impact on swallowing are not clearly understood.

In normal aging, general agreement exists that decline in the chemosensory perception of smell (Doty et al., 1984; Moeller, 1987)--including degeneration of the olfactory nerve and olfactory mucosa--is inevitable (Cain & Stevens, 1989). According to Murphy (1992), olfactory loss demonstrates significant impairment with age in studies assessing threshold sensitivity, suprathreshold intensity, suprathreshold identification, and odor memory. Older individuals' difficulty with identification of blended foods is attributed more to olfactory loss than to taste loss.

No evidence has been found to support the common generalizations that edentulous states (Chauncey, Feldman, & Wayler, 1983) and decreased saliva production (Baum, 1981) affect swallowing in older individuals. Neither decreased gustatory function (Moeller, 1987; Weiffenbach, 1984) nor decreased taste (Moeller, 1987) shows significant decrements negatively affecting swallowing ability with age.

Hollien (1987) summarized available physiologic and aerodynamic data supporting the hypothesis that respiratory function declines significantly with advancing age, thereby affecting the communication acts of the older individual. Age-related changes in the respiratory system include a decrease in diaphragmatic action, vital capacity, maximum breathing capacity (Wantz & Gay, 1981), and loss of elasticity in the lungs (Turner, Mead, & Wohl, 1968). Although the impact of respiratory alterations in speech and voice is not clear, the question of a correlation between respiratory decline and alterations in the normal swallow process cannot be overlooked.

The qualitative and quantitative characteristics of age-dependent alterations in the laryngeal structures underlying the normal swallow process have not been fully realized. As early as 1941, Bach, Lederer, and Dinolt documented age-related degenerative and atrophic changes in the laryngeal muscles. Kahane (1987) summarized reports in the aging literature that substantiated specific structural and physiological changes that occurred at the laryngeal level.

Michel et al. (1987) reported a lowering of the laryngeal position to the level of cervical vertebrae six-seven. This lowering was due to age-related cervical spine changes as well as increased dilation of the pharynx subsequent to decreased muscle tonus. The hyaline cartilages of the larynx have been found to undergo ossification with increasing age, occurring earlier and to a greater extent in males. This ossification results in decreased flexibility and increased stiffness (Kahane, 1980). Kahn and Kahane (1986) reported age-related changes in the articular surfaces of the cricoarytenoid joint, impacting on the smoothness of cartilage movement and vocal fold approximation.

The senescent voice undoubtedly relates to the manner and extent of structural and physiological changes in the tissues of the larynx (Kahane, 1987). Identifying characteristics of the nonpathologic aging voice may, in turn, aid in the identification of specific characteristics of the nonpathologic aging swallow process.

Considerable research has focused on vocal fold changes associated with aging. In the layers of the lamina propria, decreased density of collagenous and elastic fibers, thinning of elastic tissues, and thickening of collagenous fibers have been reported (Hirano, Kurita, & Nakashima, 1983; Kahane, 1983). Atrophy of the vocal folds and vocal edema (Honjo & Isshiki, 1980) has also been identified.

Age-related changes in connective tissues of the vocal folds may result in irregularities in vocal fold vibration and changes in pitch level (Hollien & Shipp, 1972; Mysak, 1959). Investigations into fundamental frequency identified a tendency toward increased fundamental frequency in aging male voices (Hollien & Shipp, 1972; Mueller, Sweeney, & Baribeau, 1984; Mysak, 1959). Pitch changes in elderly males have been attributed to fibrosis of the vocal ligament and muscle atrophy. A slight decrease in fundamental frequency in aging female voices has been reported (Heeneman & Brown, 1986; Mueller et al., 1984), and laryngeal edema consistently has been associated with pitch changes among elderly females.

Perceptual characteristics of the aging voice included altered pitch, breathiness, weakness, and hoarseness (Kent & Burkard, 1981). According to Ryan and Burk (1974), vocal fry contributed to vocal tremor, increased breathiness, and the perceptual characteristics of roughness in older voices. An age-related increase in maximum phonation duration and generalized slowing in temporal factors of speech production rate were also reported (Ryan, 1972; Ryan & Burk, 1974). Evidence for vocal intensity changes was inconclusive.

Oropharyngeal Swallowing Characteristics

In recent years, research efforts have been directed toward delineating changes in the stages of the normal swallow process associated with advanced age (Cook et al., 1994; Robbins et al., 1992; Sonies et al., 1988). It becomes apparent that the problem of defining the parameters of normal aging constitutes a fundamental difficulty in the measurement of the aging swallow process. Identification of the qualitative characteristics of age-dependent swallowing decline is made difficult by the obscurity of the normal swallow process and prevalence of disease states impacting on the swallow process. As such, there remains to be an accepted definition of exactly what features of the aging swallowing mechanism are normal.

Several investigators have attempted to qualify their general observations of normal swallowing behavior in older individuals. Baum and Bodner (1983) examined aging and oral motor function in 257 healthy subjects (range 23 to 88 years) through physical examination. Significant differences between the oldest group (> 80 years) and the youngest group (< 39 years) were found, demonstrating a significant progression in altered lip posture, tongue postural function, and masticatory muscle function with increased age.

To delineate between dipper- and tipper-type swallow patterns, Dodds et al. (1989) examined normal patterns of oral phase onset in 160 subjects with normal pharyngoesophageal structure and function using videofluoroscopy. Forty-two subjects (age > 60 years) performing three swallows of liquid barium (10 ml) were compared to 118 younger subjects (mean age 47 years).

In the Dodds et al. (1989) study, the tipper-tipper pattern accounted for 72% of the swallow patterns for all age groups combined. Chi-square analysis indicated that the dipper-dipper swallow pattern occurred significantly more often in the older group (31%), a finding that may contribute to increased oral phase duration of up to 0.5 s as reported by Cook et al. (1989).

Using videofluoroscopy, Ekberg and Feinberg (1991) evaluated deglutition in 56 asymptomatic older subjects ranging in age from 72 to 93 years (M = 83 years). Thirty-one of the subjects had no history of neurologic disease. However, the remaining subjects reported a positive history of dementia, stroke, or Parkinson's disease. The subjects performed a minimum of four swallows of liquid barium. Bolus size was not controlled.

Results in the Ekberg and Feinberg (1991) study indicated the presence of synchronous and symmetric swallowing function in only 16% of the subjects. Oral stage dysfunction, specifically oral sensorimotor incoordination (32%) and dissociation between the oral and pharyngeal stages (48%), was the most prevalent finding in the neurologically impaired group. However, in the nonneurologically impaired group, oral sensorimotor incoordination and dissociation occurred in only 3% and 26% of the group, respectively.

The effect of lingual pressure generation during isometrics and swallowing was studied in healthy young and healthy old adults (Robbins et al., 1995), using the Iowa Oral Performance Instrument. In the young group, maximum tongue blade isometric pressures were greater than for the older group. Neither tongue dorsum nor tongue tip isometric pressures were significantly greater in the young group. There were no statistically significant differences between age groups for peak lingual swallowing pressures. The authors concluded that although swallow pressure did not decline with age, the difference between maximum isometric and swallow pressure (pressure reserve) declined with age, suggesting that "as individuals grow older they may be working harder to maintain the critical pressures necessary for safe and effective bolus passage through the oropharynx" (p. M261).

The major finding among the few studies of oropharyngeal swallowing in old adults is that swallowing slows with age (Robbins et al., 1992; Shaw et al., 1990; Sonies et al., 1988; Tracy et al., 1989). Shaw et al. (1990) reported the influence of age on oral-pharyngeal bolus duration measures in normal swallowing in 14 nondysphagic subjects (age range 52-84 years) and 11 healthy young controls (age range 18-24 years) using manofluoroscopy. The authors found a significant increase in oral transit duration for the aged group ($\underline{M}$ = 0.67 s) for all volumes of liquid barium when compared to the young group ($\underline{M}$ = 0.47 s). In contrast to increased oral stage duration identified by Shaw et al., no differences in pharyngeal transit duration were found between older subjects ($\underline{M}$ = 0.44 s) and younger subjects ($\underline{M}$ = 0.37 s).

In a more recent study using manofluoroscopy, Robbins et al. (1992) evaluated the effect of normal aging on pressure and temporospatial parameters of oropharyngeal movement and bolus transit during swallowing in 80 normal volunteers. The subjects were divided into four different age groups: mean age 24, 44, 65, and 72 years.

Nine duration measures of structure or bolus movement were obtained in the Robbins et al. (1992) study. The authors reported significantly longer durations for the oldest subject group (> 70 years) in stage transition, pharyngeal transit duration, upper esophageal sphincter opening, and total swallowing duration. Longer durations with increased age were primarily accounted for by delayed initiation of maximal hyolaryngeal excursion. However, Robbins et al. failed to find an age effect for oral transit duration.

Using ultrasonography, Sonies et al. (1988) examined the effects of normal aging on the oropharyngeal phase of swallowing in 47 adults. The authors examined initiation and termination of tongue/hyoid activity in defining the oral-pharyngeal phase of swallowing. They examined three age groups: young-age (range 18-34 years), middle-age (range 35-54 years), and old-age (range 55-74 years, n = 19). Subjects completed three single dry swallows, continuous dry swallows for 10 s, and three 10-ml water swallows.

Sonies et al. (1988) found that total time of hyoid activity for dry and wet swallows increased significantly with age. For the women, the total time for dry swallows (3.41 s) and wet swallows (2.43 s) increased significantly with age. The number of consecutive dry swallows completed in 10 s (M = 1.89) in the old-age group was significantly less than that of the young-age group (M = 2.87). Duration of hyoid movement from rest to maximum anterior displacement during wet swallows was significantly longer for the old-age group (M = 1.24 s) than for the young-age group (M = 0.59 s).

For males, Sonies et al. (1988) reported no significant difference in the number of continuous dry swallows between the old-age group (M = 3.13) and the young-age group (M = 3.14). The older males demonstrated significantly longer total swallowing durations for wet swallows (M = 2.47 s) than the young-age group (M = 1.39 s) and the middle-age group (M = 1.49 s).

In the Sonies et al. (1988) study, there was a significant increase in multiple lingual gestures required to complete an oral swallow for both older men and older women. Eighty percent of the old-age group required double or triple hyoid gestures to complete the swallow, in contrast to 0% of the middle-age subjects.

The impact of bolus volume on temporal measures of oropharyngeal swallowing in 24 normal subjects using combined manometry and videofluoroscopy was studied by Tracy et al. (1989). The study consisted of three groups of subjects: Group 1 (< 30 years), Group 2 (30-59 years), and Group 3 (60-79 years). The oldest group included six subjects. The subjects performed three liquid barium swallows each in the following amounts: 1 ml, 5 ml, 10 ml, and 20 ml. Measures of oral transit duration, pharyngeal swallow delay, pharyngeal swallow response, duration of closure of laryngeal vestibule, pharyngeal peristaltic velocity, and pharyngeal peristaltic amplitude were obtained.

In the Tracy et al. (1989) study, the authors found that pharyngeal swallow delay--the interval between arrival of the bolus at the ramus and onset of purposeful laryngeal elevation--was significantly longer in the oldest group (M = 0.4 s). One other measure was systematically affected by age. Pharyngeal swallow response--the duration from onset of laryngeal elevation to upper esophageal sphincter closure--was significantly shorter in the oldest group (range 0.5-0.6 s). The authors concluded that the physiological changes accompanying age include "a weakening of the coupling between the oral and pharyngeal phases of swallowing" (p. 94).

Results of the Tracy et al. (1989) study revealed no significant differences across bolus volumes or age groups in oral transit duration (OTD), mean duration of laryngeal closure, mean velocity of pharyngeal peristaltic wave (12-14 cm/s), or mean amplitude of pharyngeal peristaltic wave (120-150 mmHg). Mean OTD for all subjects over age 30 was < 0.3 s.

Lof and Robbins (1990) studied test-retest reliability in nine durational aspects of normal oropharyngeal swallowing using videofluoroscopy in 16 subjects divided into a middle-aged group (mean age 45 years) and an old-aged group (mean age 65 years). The subjects performed three swallows each of liquid barium (2 ml) and semisolid barium (2 ml). A repeat study was performed at least three months later.

In the Lof and Robbins (1990) study, there were no effects found for age or gender. The potential range of normal within-subject variability for swallow durations was highly variable for some subjects and minimally variable for others. No significant differences were found in test-retest durations of middle-aged and old-aged subjects. For all subjects combined, mean oral transit duration was 0.50 s (liquid) and 1.11 s (semisolid); mean pharyngeal transit duration was 0.51 s (liquid) and 0.66 s (semisolid). Stage transition duration averaged -0.22 s (liquid) and -0.033 s (semisolid). Pharyngeal response duration averaged 1.14 s (liquid) and 1.13 s (semisolid).

Levine, Robbins, and Maser (1992) examined nondysphagic neurologically normal individuals aged 43 to 79 years through videofluoroscopy and cranial magnetic resonance imaging (MRI) exams. Results found slower oral swallowing durations and total swallowing durations as MRI score increased.

Using manofluorography, Dejaeger et al. (1994) examined oropharyngeal swallowing of a 10 cc liquid bolus in 16 subjects aged 75 to 85 years. They compared their performance with that of subjects aged 20 to 36 years. They examined (a) pharyngeal driving forces, (b) bolus transit time, (c) bolus velocity, and (d) amplitude of pharyngeal contraction. Results showed no significant differences in bolus transit times, bolus velocities, or amplitude of pharyngeal contraction between the two groups, although greater variability was evident in the older group. Two of three pharyngeal driving forces were also not significant: tongue driving force and oropharyngeal propulsion pump.

In the Dejaeger et al. (1994) study, qualitative differences between age groups in residue post swallow were identified. Stasis in the valleculae and piriform recesses was observed post swallow in 50% of the older group and in only 15% of the younger group. Interestingly, significantly higher tongue driving forces and pharyngeal contraction amplitudes were identified in the nonstasis group.

Further studies of pharyngeal and upper esophageal sphincter (UES) dynamics revealed significantly lower mean resting UES pressures (Fulp et al., 1990; Pelemans & Vantrappen, 1985; Wilson et al., 1990) and delayed UES relaxation (Fulp et al., 1990; Shaw et al., 1990) in older subjects. These studies suggested aging was associated with increased resistance to flow across the UES because of decreased UES compliance.

Cineradiography was used to study the influence of age on speed of peristalsis in the pharyngeal constrictor musculature (Borgstrom & Ekberg, 1988) in 70 subjects divided into three age groups: < 40 years, 50 to 60 years, and > 75 years. The old group (> 75 years) included 20 subjects with dysphagia in the presence of a grossly normal pharyngeal swallow. The authors failed to find significant age-related differences in speed of pharyngeal peristalsis and concluded that speed of peristalsis was fairly constant in the grossly normal pharynx, irrespective of dysphagia or aging. In the old group, speed of pharyngeal peristalsis ranged from 7.7 to 21.3 cm/s ($\underline{M}$ = 10.2 cm/s). Nondysphagic younger subjects obtained a mean peristaltic speed of 10.8 cm/s.

The findings of Borgstrom and Ekberg (1988) were further supported by both Tracy et al. (1989) and Wilson et al. (1990), who failed to find an age effect for pharyngeal peristalsis. Although there were no significant differences between age groups in the Borgstrom and Ekberg (1988) study, intrasubject variation reportedly increased with age. More than 50% of the subjects had variations in speed > 1 cm/s.

In a recent publication, scintigraphy was the technique used to examine the effect of age on bolus transit, pharyngeal clearance, and regional residue (Cook et al., 1994). Twenty-one healthy subjects with a mean age of 68 years (range 55-83 years) were compared with nine healthy subjects with a mean age of 28 years (range 19-37 years). Of significance was the finding that oral and pharyngeal transit durations were prolonged in the older subjects, in addition to prolonged pharyngeal clearance and pharyngeal post-swallow residual counts.

The effect of age on the coordination of the glottis and upper esophageal sphincter (UES) during swallowing was examined in 10 young-age (M = 23 years) and 10 old-age (M = 73 years) healthy adults. Through combined videoendoscopy and manometry, vocal cord adduction preceded the onset of UES relaxation for all water volumes (5-20 ml), for both age groups. Furthermore, duration of deglutitive vocal cord adduction (range 1.40 s to 3.47 s) did not differ significantly between groups. The authors concluded that coordination between deglutitive glottal closure and UES relaxation is preserved in the elderly, as well as the duration of deglutitive vocal cord adduction.

Esophageal Stage Characteristics

In a review of the esophageal stage of swallowing, Ergun and Miskovitz (1992) reported only minor changes in the structure and function of the esophagus associated with aging. Hollis and Castell (1974), as cited by the authors, found only a decrease in peristaltic amplitude in subjects over 80.

Additional studies of esophageal transit concluded that esophageal function deteriorates more significantly after age 70 (Mandelstam & Lieber, 1970). Individuals over age 70 showed increased esophageal transit duration and slower esophageal clearance. Ekberg and Feinberg (1991) found the presence of esophageal abnormalities in 36% of the 56 subjects studied (M = 83 years).

Rationale for the Study

Most of the information that exists about the older swallow has been extracted from studies of dysphagic adults, increasing our understanding of the pathogenesis of swallowing. The few studies that have attempted to quantify normal oropharyngeal swallowing, particularly in the older population, have presented some interesting and often conflicting results. Systematic, quantitative techniques must be applied to samples of the normal population of older persons to delineate a continuum of subclinical changes in oropharyngeal swallowing. Using videofluoroscopy, the coordinated sequence of intricate motor and sensory events in swallowing can be examined to determine the nature of differences in age-related swallow function and the extent to which such differences exist.

The purpose of this study was to investigate age effects in oropharyngeal swallowing among three groups of nondysphagic adult men over age 50. Specifically, the study was designed to determine whether significant differences in temporo-spatial and morpho-physiological oropharyngeal swallowing events occur as a function of age and whether the differences reflect a continuum of change associated with age.

CHAPTER III

METHOD

Participants

Participants in this study consisted of 30 competent, nondysphagic adult men ranging in age from 50.4 years to 75.3 years, grouped into three age categories: Group 1 included 10 men aged 50.4 to 54.7 years (M = 52.8, SD = 1.55); Group 2 consisted of 10 men ranging in age from 60.8 to 64.8 years (M = 62.9, SD = 1.52); and Group 3 consisted of 10 men aged 70.2 to 75.3 years (M = 72.8, SD = 1.9). Although postmenopausal and surgically sterile women were not excluded from participation, no women met the criteria for inclusion.

Participants were recruited from competent inpatients and outpatients at the Veterans Affairs (VA) Medical Center in Battle Creek, Michigan. Outpatients were registered in the Audiology and Speech Pathology Service (126), and inpatients were recruited from the Medical Rehabilitation Ward (82-2) and the Post Traumatic Stress Disorder Ward (12). Incompetent subjects were excluded from this study. Competence was determined and documented by the consenting physician on VA Standard Form 513.

Consent for Participation

This study was approved by the University Committee on Research Involving Human Subjects (UCRIHS #93-354) at Michigan State University and the Subcommittee on Human Studies of the Department of Veterans Affairs Medical Center in Battle Creek, Michigan. Participants were provided with a verbal and written description of the research by the principal investigator and gave their informed consent by signing the VA Research Consent Form #10-1086 (Appendix A). The consent form apprised participants of the (a) purpose of the study; (b) description of the study and procedures; (c) discomforts, potential reactions, and risks associated with ingestion of barium sulfate and exposure to radiation from the videofluoroscopy x-ray procedure; (d) benefits of participation; and (e) rights associated with participation.

Physicians' consent was documented for all participants prior to participation in the study on VA Standard Form 513. The physician verified and documented (a) absence of allergy history that would interfere with ingestion of the barium sulfate, (b) absence of medication use that could pose any risk associated with the videofluoroscopy x-ray procedure, and (c) competency. For all subjects accepted into the study, a progress note was written by the principal investigator on the medical chart, stating (a) the VA Research Consent Form #10-1086 was discussed with the subject, (b) the subject was mentally competent, and (c) the subject understood and agreed to participate in the study.

Health History Questionnaire

All participants recruited for the study completed a Health History Questionnaire (HHQ) administered by the principal investigator (Appendix B). Medical charts were reviewed, and physician contact was made when verification of medical status was required. Specifically, the questionnaire obtained information from the subject on 68 health conditions organized into five categories: medical, surgical, speech, voice, and swallowing. Subjects with a reported or documented history in any one of these 68 health conditions that were judged by the principal investigator to interfere with the normal swallow process or with the videofluoroscopy x-ray procedure were eliminated from the study.

Because of the risks associated with swallowing barium sulfate in the presence of certain preexisting conditions, subjects were not allowed to participate in this study if they had (a) a known obstruction of the colon; (b) suspected or impending gastrointestinal perforation; (c) hypersensitivity to barium sulfate products; (d) bronchial asthma; (e) history of multiple (greater than three) food or drug allergies; (f) a history of allergies as evidenced by hayfever and eczema; or (g) used medications that contained a topical anesthetic agent like those in mouthwashes (e.g., Listerine), sore throat products (e.g., Cepacol, Vicks, Cepastat, and Chloraseptic), cough medicines, or products for tooth or gum pain (e.g., Orajel, Orabase, Anebesol) within one to two hours prior to participation in the videofluoroscopy x-ray procedure.

Dysphagia Screening

Subjects receiving a passing score on the Health History Questionnaire were administered the Dysphagia Screening Instrument (DSI) by the principal investigator. The DSI was administered to rule out the presence of swallowing difficulty and determine eligibility for further participation in the study.

Phases of Development

In the first phase of development, 10 certified speech-language pathologists (SLPs) completed an open-item questionnaire designed to elicit specific components included in a dysphagia screening. Five areas were probed: respiration, phonation, resonation, articulation, and nonspeech. They were asked to generate a list of tasks that they would perform during a swallowing screening. From this questionnaire, a total of 42 different structural and physiologic dysphagia screening components were identified by the responding SLPs (see Table C1, Appendix C).

A 42-item swallowing questionnaire was then developed from the responses generated in the first phase. Twelve SLPs with dysphagia experience ranging from 1 to 19 years (M = 6.75 years) participated in the second phase of the DSI development. The SLPs were required to rate each of the 42 items individually by determining whether the key item would be an effective indicator of oropharyngeal dysphagia in the elderly population.

The SLPs were asked to answer yes or no to the following question (no operational definitions for the terms "abnormal," "oropharyngeal dysphagia," or "elderly" were provided):

> If this parameter was abnormal, would it be an effective indicator of oropharyngeal dysphagia in the elderly population?

Of the original 42 items, 15 target areas were identified to be effective predictors of oropharyngeal dysphagia in the elderly population by receiving a positive predictive score by at least 66% (n = 8) of the respondents. The 15 target areas were (a) labial seal, (b) lingual sensation, (c) lingual elevation, (d) lingual lateralization, (e) lingual strength, (f) lingual symmetry, (g) posterior tongue diadochokinetic rate, (h) voluntary cough, (i) reflexive cough, (j) involuntary swallow, (k) voluntary dry swallow, (l) voluntary liquid swallow, (m) laryngeal elevation, (n) vocal quality, and (o) saliva control.

In the final phase of development, 10 of the 12 original respondents further rated each of the 15 target areas, using a five-point rating scale. They completed a questionnaire that required a rating of how effective each parameter would be in predicting oropharyngeal dysphagia in the elderly if that parameter was abnormal. Scores ranged from a rating of 1 (extremely ineffective) to a rating of 5 (extremely effective). Again, no operational definitions of abnormal, oropharyngeal, dysphagia, or elderly were provided. Each of the 15 target areas received a rating score of either 4 (effective) or 5 (extremely effective) in their predicting ability. No area was judged to be an ineffective predictor by any of the respondents.

Dysphagia Screening Instrument

The final format for the Dysphagic Screening Instrument (DSI) was constructed from these 15 target areas (Appendix D). The DSI consisted of 15 screening task items. Eight oral-motor tasks to screen motor and sensory capabilities of the swallowing mechanism were adapted from Love and Webb (1992): lingual sensation, lingual strength, tongue tip elevation, lingual lateralization, lingual symmetry, labial seal, reflexive cough, and saliva control. The remaining seven DSI screening tasks involved assessment of alternate motion rate (Fletcher, 1972), vocal quality and voluntary cough (Aronson, 1990), involuntary swallow (Dodds et al., 1990), voluntary dry swallow (Sonies et al., 1988), and voluntary liquid swallow and laryngeal elevation (Logemann, 1983).

Subjects who passed the Health History Questionnaire and qualified for further participation completed the Dysphagia Screening Instrument (DSI). Each task on the DSI was administered to the subjects by the principal investigator in the order outlined on the DSI. Functional performance for each of the 15 tasks was subjectively scored by the examiner as 1 (accurate, immediate, and without cues) or 0 (inaccurate, delayed, or with verbal/tactile cues). The total score possible was 15. Subjects scoring less than 15 were excluded from the study. Subjects successfully passing the DSI completed a Videofluoroscopic Swallow Study (VFSS) of oropharyngeal swallow structure and function. The delay between completion of the DSI and participation in the VFSS averaged 11.03 days (range 0-30 days).

Equipment and Materials

The videofluoroscopy swallow study (VFSS) recordings were obtained from a General Electric Prestilix (Model #1690s) using a six-inch image magnifier. Data from the fluoroscopic image were recorded on a JVC Super VHS Player/Recorder

(#BR 8611U), with a 3M Master Broadcast Anti-Stat Super VHS Videocassette 3/4" tape run at 30 frames/s. Data were viewed on a 13-in Panasonic Color S-Video Monitor (#CT 1383 Y). The tape recorder was coupled to a Panasonic Time/Date Generator (#WJ-810), allowing frame-by-frame analysis of duration measures in ms for each swallow. Data analysis was performed using the same videocassette tape recorder and color monitor.

VFSS recordings of the oral cavity and pharynx were obtained at 70 to 80 KeV. Fluoroscopic exposure was limited to < 10 s for each test bolus. If the swallow duration exceeded 10 s, fluoroscopy was deactivated. Total exposure ranged from 41 to 144 s in duration per subject. Average exposure was 76 s.

The test materials consisted of EZ Paste Barium Sulfate Cream (120% wt/vol), coated onto a hard cookie (Lorna Doone), and EZPAQUE liquid barium (95% wt/vol). The liquid barium test boluses were prepared 15 minutes before the VFSS procedure, then shaken for 10 seconds immediately prior to the swallow. The liquid barium test boluses were presented in 5.0 ml volumes. For the solid test boluses, 2.0 ml of barium paste was coated onto a 1.0 oz cookie test bolus.

Videofluoroscopic Swallow Study

The protocol for completion of the Videofluoroscopy Swallow Study (VFSS) for each subject remained constant (Appendix E). The VFSS was conducted by the principal investigator and the Chief of Radiology at the Veterans Affairs Medical Center in Battle Creek, Michigan, with assistance provided by a radiological technician at the discretion of the Chief, Radiology Service.

Each subject was examined while seated upright on a bench attached to the General Electric Prestlix table in the fluoroscopy suite. The distance between the fluoroscopy table and tube remained constant (< 3 feet) for each subject. Subjects were viewed in the lateral plane, allowing for visibility of the lips, teeth, tongue, palate, velum, mandible, pharyngeal wall, cervical vertebrae, hyoid bone, larynx, and upper esophageal sphincter. The margins in focus included the lips anteriorly, the pharyngeal wall posteriorly, the hard palate superiorly, and the seventh cervical vertebra inferiorly.

The test boluses were administered by the principal investigator. The liquid barium was swallowed first, being self-administered by the subject. The subject was instructed to hold the liquid test bolus in the mouth until the command to swallow was given and then to swallow naturally and normally. Fluoroscopy was activated just before the command to swallow and deactivated after the bolus tail passed through the upper esophageal sphincter.

The barium-paste-coated cookie test trials were completed after the liquid trials. The subject was instructed to chew the barium-paste-coated cookie, signal to the principal investigator when he was ready to swallow, then swallow naturally and normally. Fluoroscopy was activated just before the command to swallow and deactivated after the bolus tail passed through the upper esophageal sphincter.

Each subject participated in one testing session, during which a total of six swallows were performed and recorded: three swallows of liquid barium followed by three swallows of a barium-paste-coated cookie. Presentation of test boluses were not counterbalanced. The liquid barium was presented first for all subjects to eliminate the likelihood that residue from solid swallows would interfere with imaging.

Videofluoroscopic Analysis

Seven swallowing events were determined for each swallow for each subject: five temporo-spatial events and two morpho-physiologic events. Seven dependent variables were then calculated from these swallowing events.

Swallowing Duration Measures

Timing of five temporo-spatial swallowing events was determined by reading the digital clock (in ms) recorded on each frame of the videotape for each swallow, for each subject. The five temporo-spatial swallowing events were identified by (a) time at which posterior bolus head movement in the oral cavity began, (b) time at which the head of the bolus first reached the ramus of the mandible, (c) time at which the hyoid began maximal vertical excursion, (d) time at which the bolus tail passed through the upper esophageal sphincter, and (e) time at which the hyoid returned to rest.

Five dependent variables--oropharyngeal swallowing duration measures--were then calculated from these temporo-spatial swallowing events for each swallow for each subject following the protocol outlined by Lof and Robbins (1990): three bolus duration measures and two temporo-spatial duration measures. The five dependent variables (in ms) were (a) oral transit duration (OTD)--time at which posterior bolus movement in the oral cavity began until the head of the bolus entered the pharynx, i.e., first reached the ramus of the mandible, (b) pharyngeal transit duration (PTD)--time at which the head of the bolus first reached the ramus of the mandible until the bolus tail passed through the upper esophageal sphincter, (c) total swallowing duration (TSD)--time at which the bolus began to move posteriorly until the tail of the bolus passed through the UES, (d) stage transition duration (STD)--time at which the bolus head reached the ramus of the mandible until the hyoid began maximal upward excursion, and (e) hyo-laryngeal response duration (HLD)--time at which the hyoid began maximal upward excursion until the hyoid returned to rest.

Morpho-physiological Measures

Two of the remaining seven swallowing events were identified through videofluoroscopic analysis for each swallow for each subject. The two morpho-physiologic dependent variables were oral bolus position (OBP) and stage transition pattern (STP). OBP was defined as the antero-postero position of the bolus head on the superior surface of the tongue prior to posterior bolus movement during the oral stage of the swallow. OBP was identified as anterior, mid, or posterior; i.e., the bolus head was visible on the anterior 1/3 of the tongue, middle 1/3 of the tongue, or posterior 1/3 of the tongue surface prior to swallow initiation. Antero-postero demarcations included the lips anteriorly and the ramus of the mandible posteriorly.

Stage transition pattern (STP) was defined as the presence of a continuous stage transition pattern (CSTP) or an interrupted stage transition pattern (ISTP) of bolus movement through the oral and pharyngeal stage of the swallow. A CSTP was characterized by continuous movement of the test bolus through the oropharynx without visible hesitation between the oral and pharyngeal stages of swallowing. An ISTP was characterized by interrupted movement of the test bolus through the oropharynx with visible hesitation of the bolus between the oral and pharyngeal stages of swallowing.

Training Procedure

Each swallow was examined on the videocassette tape recorder in normal speed, slow motion, and frame-by-frame by the principal investigator. Frame-by-frame analysis was utilized for data collection and analysis.

Two additional judges, speech-language pathologists with experience interpreting videofluoroscopic evaluations of dysphagia, participated in the videofluoroscopy swallow study (VFSS) analysis following completion of a training session by the principal investigator.

In the training session, three VFSS samples of normal adult subjects swallowing a 5 cc liquid barium bolus were reviewed on videotape by each of the judges. The judges received instruction on identification of video frames corresponding to five temporo-spatial swallowing events. Definitions and examples of each swallowing event were provided. The judges were then required to identify the video frame corresponding to five temporo-spatial swallowing events by noting and recording the time (in ms) at which the event occurred. If inter-judge differences exceeded 0.1 s, continued instruction on the same swallow samples was provided until interjudge differences averaged less than 0.1 s for each of the five temporo-spatial swallowing events for each of the three sample swallows.

The judges received instruction on identification of the two morpho-physiologic swallowing events: oral bolus position and stage transition pattern. Definitions and examples of each swallowing event were provided. The judges were then required to make observations on the two morpho-physiologic swallowing events for each of the three sample swallows. If inter-judge agreement was less than 90%, continued instruction was provided until all three judges reached 100% agreement on both oral bolus position and stage transition pattern for each of the three sample swallows.

Reliability

Intrajudge Reliability

Intrajudge reliability in identification of the seven swallowing events was assessed by having each of the three judges repeat their analysis of two randomly selected video-fluoroscopic taped samples from each age group. For each of the five temporo-spatial oropharyngeal swallowing events, average intrajudge differences in scoring between the first and second analysis of 0.1 s or less were considered a priori as reliable. For the two morpho-physiologic events, 90% agreement between the first and second analysis was required.

Interjudge Reliability

Interjudge reliability in identification of the seven swallowing events was determined a priori by requiring two of three judges to obtain agreement within 0.1 s for each of the five temporo-spatial swallowing events on one randomly selected videofluoroscopic taped sample from each age group. For the two morpho-physiologic swallowing events, 90% agreement between two of three examiners was required. After completion of the VFSS analysis, judges were required to rate their level of confidence in data collection and analysis for each subject on a scale ranging from 1 (not confident) to 5 (very confident).

Statistical Analysis

Statistical analysis of five dependent variables--oropharyngeal swallowing duration measures--was completed using the mean values of the three swallows by each subject for each texture, to obtain the group mean. A one-way simple factorial analysis of variance (ANOVA) using the computer program SPSS (Statistical Data Analysis, 1989) was completed for each of the five durational dependent variables using a $p < .05$ level of significance: (a) oral transit duration, (b) pharyngeal transit duration, (c) total oropharyngeal swallowing duration, (d) stage transition duration, and (e) hyo-laryngeal response duration.

Chi-square analysis ($p < .05$) was performed on the two morpho-physiological dependent variables to determine whether age-related differences existed in oral bolus position and stage transition pattern. Intrajudge and interjudge reliabilities were determined by performing a Pearson product-moment correlation coefficient and index of determination.

CHAPTER IV

RESULTS

To understand the normal swallow process across the adult life span, this research was designed to identify systematic differences in oropharyngeal swallowing physiology among normal nondysphagic older adults. This study consisted of 30 adult male veterans, divided into three age groups: Group 1 (50-55 years), Group 2 (60-65 years), and Group 3 (70-75 years).

A Health History Questionnaire (HHQ) was administered to the subjects to rule out the presence of dysphagia or medical conditions associated with dysphagia. No subjects reported a history of speech, voice, or swallowing problems preceding the Videofluoroscopy Swallow Study. Medical and surgical history were negative for the presence of conditions, disease states, or medication use that has been associated with swallowing difficulty.

The Dysphagia Screening Instrument (DSI) was then completed for each subject to further rule out the presence of swallowing difficulty. Subjects receiving a passing score of 15 participated in the videofluoroscopy x-ray procedure.

The Videofluoroscopy Swallow Study (VFSS) measured seven dependent variables. Five durational dependent variables were calculated: oral transit duration

(OTD), pharyngeal transit duration (PTD), total oropharyngeal swallowing duration (TOSD), stage transition duration (STD), and hyo-laryngeal response duration (HLD). Two morpho-physiological dependent variables were measured: oral bolus position (OBP) and stage transition pattern (STP).

Oropharyngeal Swallowing Measures

Liquid Barium Swallows

No participants reported a subjective difficulty swallowing any of the three liquid test boluses during the Videofluoroscopy Swallow Study. Central tendency and variability data were calculated and summarized for five oropharyngeal swallowing durations of a 5 cc liquid barium bolus (Table 1).

Table 1: Central tendency and variability data for 5 cc liquid barium oropharyngeal swallowing durations (in seconds) in adults of different ages.

Group	Measure	Swallowing Durations				
		OTD	PTD	TOSD	STD	HLD
50-55	M	0.27	0.61	0.88	-0.30	1.41
	SD	0.17	0.16	0.22	0.11	0.30
	Range	0.07 - 0.64	0.46 - 1.01	0.65 - 1.25	-0.16 - -0.50	1.12 - 1.90
60-65	M	0.28	0.70	1.00	-0.20	1.32
	SD	0.11	0.15	0.20	0.23	0.33
	Range	0.13 - 0.42	0.47 - 0.95	0.66 - 1.27	-0.55 - 0.14	0.80 - 1.84
70-75	M	0.27	0.67	0.94	-0.21	1.35
	SD	0.10	0.09	0.12	0.17	0.26
	Range	0.13 - 0.44	0.56 - 0.79	0.82 - 1.16	-0.43 - 0.07	1.03 - 1.80

Note. M (mean), SD (standard deviation), OTD (oral transit duration), PTD (pharyngeal transit duration), TOSD (total oropharyngeal swallowing duration), STD (stage transition duration), HLD (hyo-laryngeal response duration).

The mean liquid swallowing durations for each age group were compared (Figure 1). The mean oral transit duration for all groups was less than 0.30 s. Mean pharyngeal transit duration for all age groups ranged between 0.61 s and 0.7 s. The mean total oropharyngeal swallowing duration (TOSD) did not exceed 1.0 s for any of the age groups. The mean value for stage transition duration was negative for all groups; i.e., the hyoid began maximal vertical excursion prior to the bolus head reaching the ramus. Hyo-laryngeal response duration exceeded TOSD for all age groups and was the longest measured event for liquid swallows.

Analysis of variance (ANOVA) revealed no significant differences among the three age groups in oropharyngeal swallowing duration measures for a 5 cc liquid barium bolus (Table 2). An F ratio of 3.37 was required for significance at $p < .05$.

Oral bolus position data for 5 cc liquid barium swallows for each of the three age groups were summarized (Table 3). Eighty-four swallows were analyzed. A determination could not be made on six swallows, three of each in Groups 1 and 3. For liquid swallows, mid placement occurred in 59.3% of the youngest group, 53.3% of the middle-age group, and only 29.6% of the oldest group (Figure 2). Posterior placement was observed in only 14.8% of the youngest group as compared to 48.1% of the oldest group.

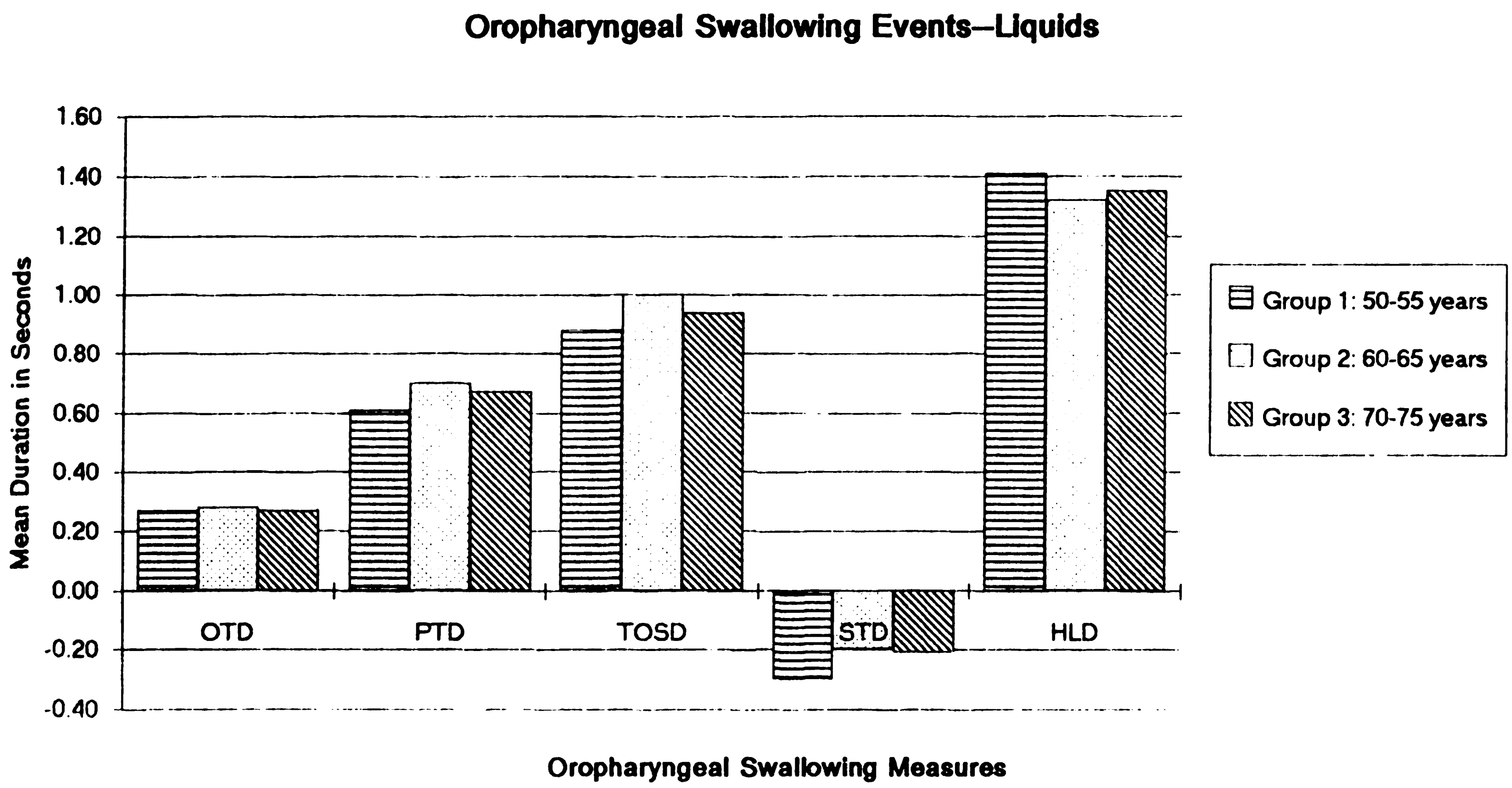

Figure 1: Mean oropharyngeal swallowing durations for 5 cc liquid barium swallows for three age groups. OTD (oral transit duration), PTD (pharyngeal transit duration), TOSD (total oropharyngeal swallowing duration), STD (stage transition duration), HLD (hyo-laryngeal response duration).

Table 2: Analysis of variance for 5 cc liquid barium swallowing duration measures in adults of different ages.

Source	df	SS	MS	F
OTD				
Between (age)	2	.001	.000	.024
Within	27	.447	.017	
PTD				
Between (age)	2	.039	.019	1.037
Within	27	.504	.019	
TOSD				
Between (age)	2	.074	.037	1.082
Within	27	.929	.034	
STD				
Between (age)	2	.059	.030	.967
Within	27	.829	.031	
HLD				
Between (age)	2	.048	.024	.271
Within	27	2.378	.088	

Note. An F ratio of 3.37 was required for significance at $p < .05$. OTD (oral transit duration), PTD (pharyngeal transit duration), TOSD (total oropharyngeal swallowing duration), STD (stage transition duration), HLD (hyo-laryngeal response duration).

Table 3: Oral bolus position (OBP) for 5 cc liquid barium swallows in adults of different ages.

Position	Age Group		
	50-55	60-65	70-75
ANT	7	6	6
MID	16	16	8
POST	4	8	13

Note. OBP (oral bolus position = antero-postero position of the bolus head on the superior surface of the tongue prior to posterior bolus movement during the oral stage of the swallow), ANT (anterior = bolus head positioned on the anterior 1/3 of the tongue), MID (middle = bolus head positioned on the middle 1/3 of the tongue), POST (posterior = bolus head positioned on the posterior 1/3 of the tongue).

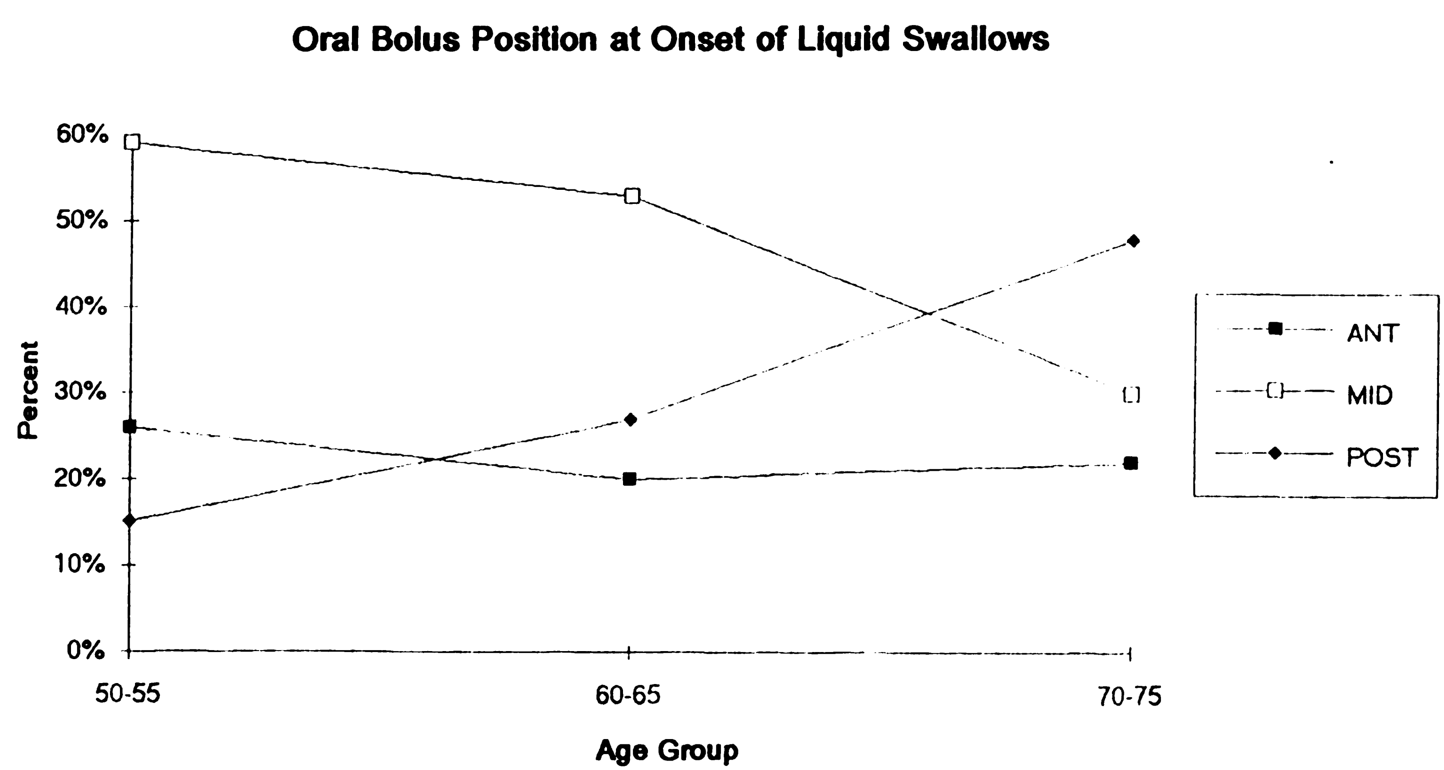

Figure 2: Oral bolus position (OBP) at onset of 5 cc liquid barium swallows for three age groups. ANT (bolus head positioned on the anterior 1/3 of the tongue), MID (bolus head positioned on the middle 1/3 of the tongue), POST (bolus head positioned on the posterior 1/3 of the tongue).

There were no statistically significant differences among the three age groups in oral bolus position for liquid swallows based on the Pearson chi-square statistic (χ^2 = 8.2225, $\underline{df}$ = 4, $\underline{n}$ = 84, $\underline{p} \leq .05$). A chi-square value of 9.488 was required for significance at the $\underline{p} < .05$ level. The contingency coefficient was .29860.

Differences among the three age groups were significant at $\underline{p} < .08376$, based on the Pearson chi-square statistic. Age effects in oral bolus position were observed between Groups 1 and 3 (χ^2 = 7.50830, $\underline{df}$ = 1, $\underline{n}$ = 54, $\underline{p} \leq .05$). Age effects were not observed between Groups 1 and 2 (χ^2 = 1.25584, $\underline{df}$ = 1, $\underline{n}$ = 57, $\underline{p} \leq .05$) or between Groups 2 and 3 (χ^2 = 3.70952, $\underline{df}$ = 1, $\underline{n}$ = 57, $\underline{p} \leq .05$). For 1 $\underline{df}$, a chi-square value of 3.841 was required for significance at the $\underline{p} < .05$ level.

Stage transition pattern (STP) data for liquid swallows for the three age groups were calculated (Table 4). A total of 84 swallows were analyzed. STP for six swallows could not be determined: three each in Groups 1 and 3.

Table 4: Stage transition pattern (STP) for 5 cc liquid barium swallows in adults of different ages.

Pattern	Age Group		
	50-55	60-65	70-75
CSTP	22	13	8
ISTP	5	17	19

Note. STP (stage transition pattern), CSTP (continuous stage transition pattern = continuous movement of the test bolus through the oropharynx without visible hesitation between the oral and pharyngeal stages of swallowing), ISTP (interrupted stage transition pattern = interrupted movement of the test bolus through the oropharynx with visible hesitation of the bolus between the oral and pharyngeal stages of swallowing).

A continuous stage transition pattern (CSTP) was observed more frequently in the 50 to 55 year age group (Figure 3). A CSTP was observed in 81.5% (Group 1), 43.3% (Group 2), and 29.6% (Group 3) of the liquid swallows. In contrast, an interrupted stage transition pattern (ISTP) for liquid swallows was observed more often in the 60 to 65 and 70 to 75 year age groups. An ISTP for liquid swallows was observed in only 18.5% of the youngest group as compared to 56.7% and 70.4% of the two oldest groups.

Stage transition pattern for liquids reached statistical significance for the three age groups based on the Pearson chi-square statistic ($\chi^2 = 15.67979$, $\underline{df} = 2$, $\underline{n} = 84$, $\underline{p} < .05$). A chi-square value of 5.991 was required for significance at the .05 level. The contingency coefficient was .39661.

Further analysis revealed significant differences in stage transition pattern (STP) between Groups 1 and 2 ($\chi^2 = 8.72602$, $\underline{df} = 1$, $\underline{n} = 57$, $\underline{p} < .05$) and Groups 1 and 3 ($\chi^2 = 14.70000$, $\underline{df} = 1$, $\underline{n} = 54$, $\underline{p} < .05$). There were no significant differences in STP for liquid swallows between the two oldest groups ($\chi^2 = 1.14687$, $\underline{df} = 1$, $\underline{n} = 57$, $\underline{p} < .05$). For 1 df, a chi-square value of 3.841 was required for significance at the .05 level.

Solid Barium Swallows

No subjects reported a difficulty swallowing any of the three solid test boluses during the Videofluoroscopy Swallow Study. Aspiration was not observed in any subject. Central tendency and variability data were calculated and summarized for

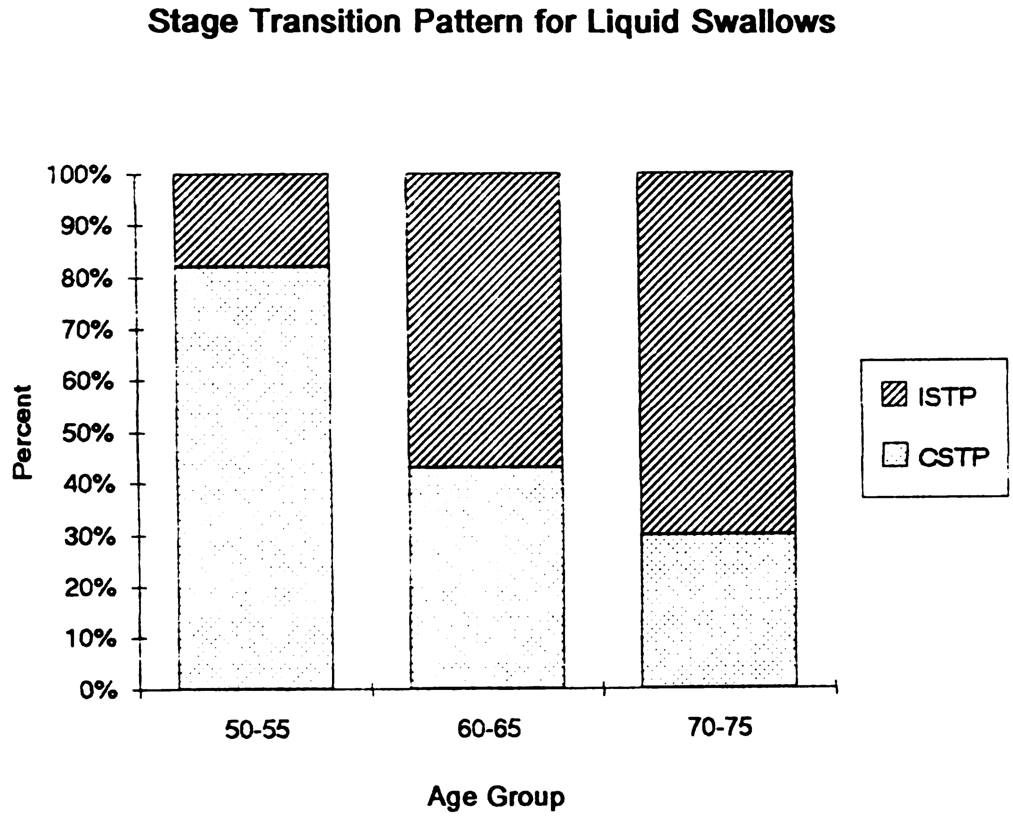

Figure 3: Stage transition pattern (STP) for 5 cc liquid barium swallows for three age groups. CSTP (continuous movement of the test bolus through the oropharynx without visible hesitation between the oral and pharyngeal stages of swallowing, ISTP (interrupted movement of the test bolus through the oropharynx with visible hesitation between the oral and pharyngeal stages of swallowing).

five oropharyngeal swallowing durations of a 2 cc barium-paste-coated cookie (Table 5).

Table 5: Central tendency and variability data for oropharyngeal swallowing durations (in seconds) of barium-paste-coated cookie swallows in adults of different ages.

Group	Measure	Swallowing Durations				
		OTD	PTD	TOSD	STD	HLD
50-55	M	0.41	0.81	1.22	-0.10	1.41
	SD	0.26	0.41	0.48	0.27	0.38
	Range	0.16 - 0.81	0.41 - 1.83	0.71 - 2.16	-0.42 - -0.48	0.97 - 2.03
60-65	M	0.54	0.86	1.41	0.03	1.43
	SD	0.25	0.23	0.39	0.26	0.39
	Range	0.16 - 0.94	0.54 - 1.30	0.76 - 2.06	-0.34 - 0.50	1.04 - 2.14
70-75	M	0.54	0.78	1.32	-0.05	1.28
	SD	0.25	0.20	0.42	0.36	0.32
	Range	0.28 - 0.96	0.48 - 1.29	0.76 - 2.25	-0.66 - 0.63	0.96 - 2.01

Note. M (mean), SD (standard deviation), OTD (oral transit duration), PTD (pharyngeal transit duration), TOSD (total oropharyngeal swallowing duration), STD (stage transition duration), HLD (hyo-laryngeal response duration).

The mean durations for solid swallows in each age group were compared (Figure 4). The mean oral transit duration for all age groups approximated one-half second, and the mean pharyngeal transit duration ranged from 0.78 s to 0.86 s. The mean total oropharyngeal swallowing duration (TOSD) for all age groups was greater than 1.0 s. Mean hyo-laryngeal response duration (HLD) ranged from 1.28 s to 1.43 s. In addition, the mean HLD was longer than TOSD for the two youngest groups and shorter than TOSD in the oldest group.

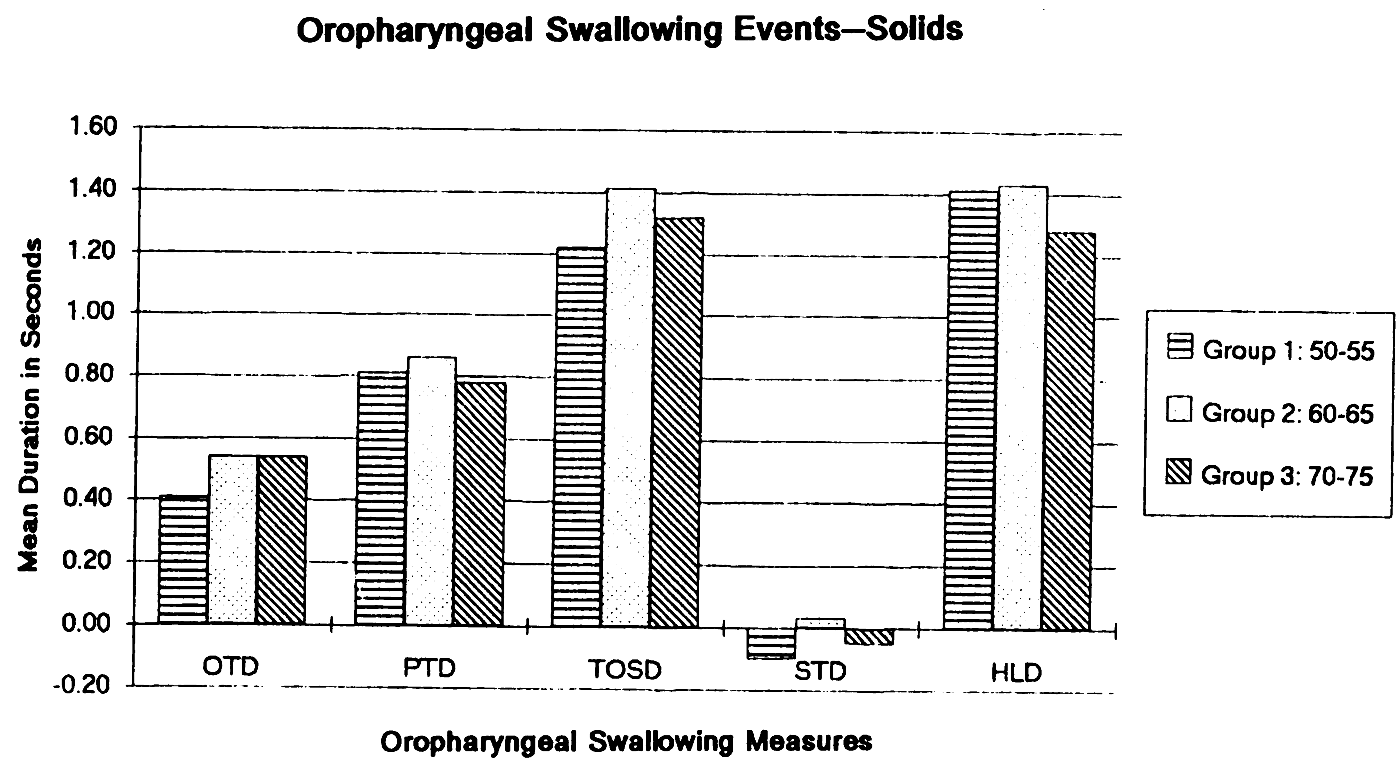

Figure 4: Mean oropharyngeal swallowing durations for barium-paste-coated cookie swallows for three age groups. OTD (oral transit duration), PTD (pharyngeal transit duration), TOSD (total oropharyngeal swallowing duration), STD (stage transition duration), HLD (hyo-laryngeal response duration).

Analysis of variance (ANOVA) revealed no significant differences among the three age groups in oropharyngeal swallowing duration measures for barium-paste-coated cookie swallows (Table 6). An F ratio of 3.37 was required for significance at $p < .05$.

Table 6: Analysis of variance (ANOVA) for barium-paste-coated cookie swallowing duration measures in adults of different ages.

Source	df	SS	MS	F
OTD				
Between (age)	2	.113	.056	.970
Within	27	1.570	.058	
PTD				
Between (age)	2	.037	.018	.186
Within	27	2.660	.099	
TOSD				
Between (age)	2	.071	.086	.463
Within	27	4.991	.185	
STD				
Between (age)	2	.095	.047	.525
Within	27	2.434	.090	
HLD				
Between (age)	2	.124	.062	.465
Within	27	3.609	.134	

Note. An F ratio of 3.37 was required for significance at $p < .05$. OTD (oral transit duration), PTD (pharyngeal transit duration), TOSD (total oropharyngeal swallowing duration), STD (stage transition duration), HLD (hyo-laryngeal response duration).

Oral bolus position (OBP) data for solid barium swallows were summarized (Table 7). A determination of OBP could not be made on 10 swallows: four (Group 1), one (Group 2), and five (Group 3).

Table 7: Oral bolus position (OBP) for barium-paste-coated cookie swallows in adults of different ages.

Pattern	Age Group		
	50-55	60-65	70-75
ANT	12	7	6
MID	11	18	17
POST	3	4	2

Note. OBP (oral bolus position = antero-postero position of the bolus head on the superior surface of the tongue prior to posterior bolus movement during the oral stage of the swallow), ANT (anterior = bolus head positioned on the anterior 1/3 of the tongue), MID (middle = bolus head positioned on the middle 1/3 of the tongue), POST (posterior = bolus head positioned on the posterior 1/3 of the tongue).

For all swallows combined, mid OBP was the most frequently observed placement (57.5%), followed in turn by anterior (31.3%) and posterior (11.3%) placement (Figure 5). For oral bolus position, anterior placement occurred in 46.2% (Group 1), 24.1% (Group 2), and 24% (Group 3) of the solid swallows. Mid placement occurred in 42.3% (Group 1), 62.1% (Group 2), and 68.0% (Group 3) of the solid swallows. Posterior placement prior to initiation of the swallow was observed in 11.5% (Group 1), 13.8% (Group 2), and 8.0% (Group 3) of the solid swallows.

There was no effect due to age in oral bolus position for solid swallows based on the Pearson chi-square statistic ($\chi^2 = 4.76961$, $df = 4$, $n = 80$, $p \leq .05$). A chi-square value of 9.488 was required for significance at the .05 level. The contingency coefficient was .23720.

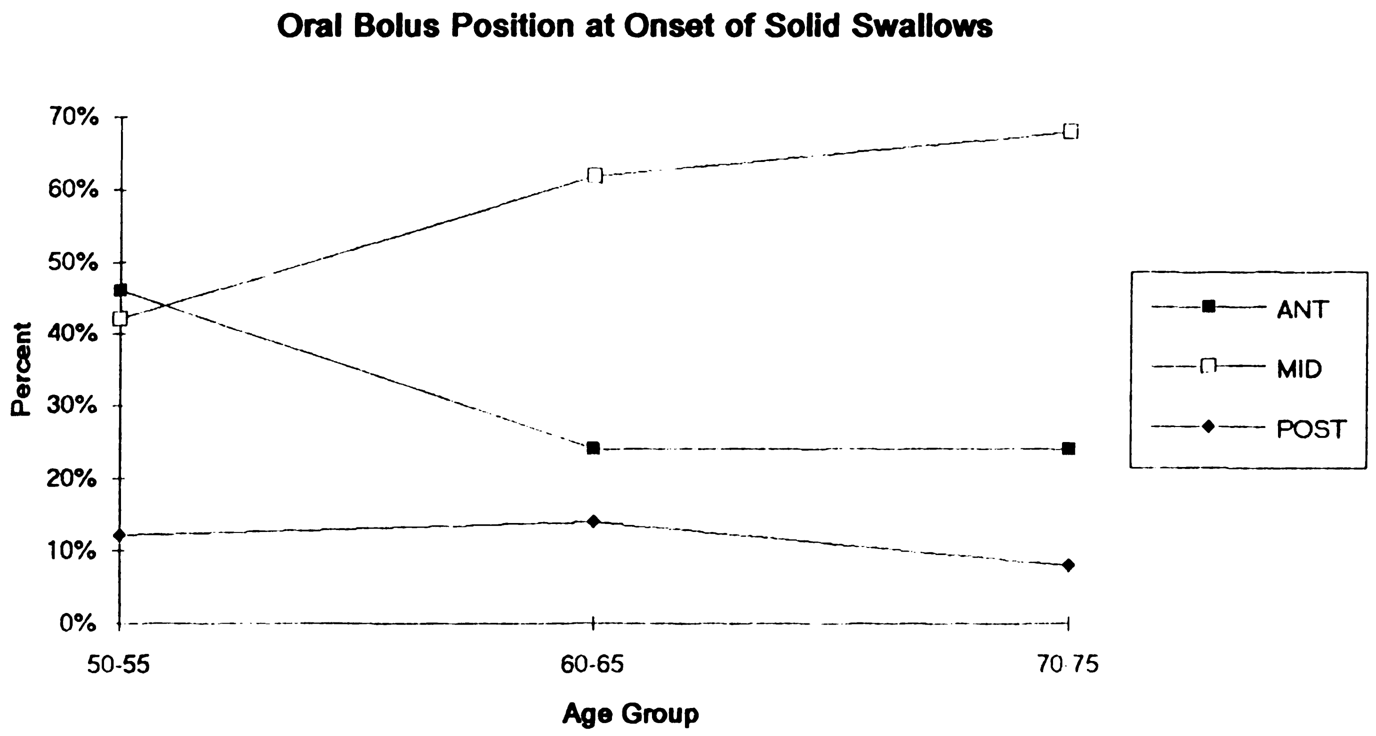

Figure 5: Oral bolus position (OBP) at onset of barium-paste-coated cookie swallows for three age groups. ANT (bolus head positioned on the anterior 1/3 of the tongue), MID (bolus head positioned on the middle 1/3 of the tongue, POST (bolus head positioned on the posterior 1/3 of the tongue).

Data for stage transition pattern (STP) were summarized (Table 8). A total of 78 swallows were analyzed. Twelve swallows could not be analyzed for STP: five in the youngest group, one in the middle-aged group, and six in the oldest group. Group 1 was more likely to display a continuous stage transition pattern (64%) for solid swallows, as compared to 10% and 17% for Groups 2 and 3, respectively (Figure 6). An interrupted stage transition pattern for solids predominated for Group 2 (90%) and Group 3 (83%).

Table 8: Stage transition pattern (STP) for barium-paste-coated cookie swallows in adults of different ages.

Pattern	Age Group		
	50-55	60-65	70-75
CSTP	16	3	4
ISTP	9	26	20

Note. STP (stage transition pattern), CSTP (continuous stage transition pattern = continuous movement of the test bolus through the oropharynx without visible hesitation between the oral and pharyngeal stages of swallowing), ISTP (interrupted stage transition pattern = interrupted movement of the test bolus through the oropharynx with visible hesitation of the bolus between the oral and pharyngeal stages of swallowing).

A Pearson chi-square statistic revealed significant differences among the three age groups in stage transition pattern for solid swallows ($\chi^2 = 21.32988$, $df = 2$, $n = 78$, $p \leq .05$). For 2 df, a chi-square of 5.991 was required for significance at the .05 level. The contingency coefficient was .46340.

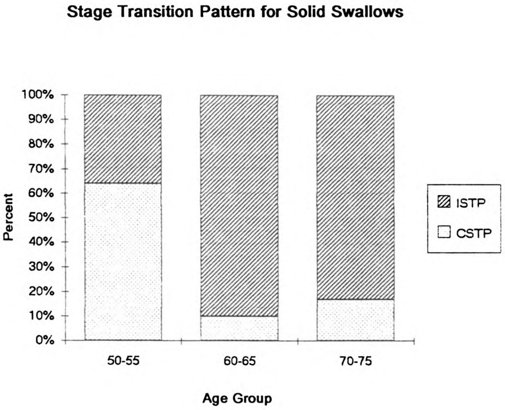

Figure 6: Stage transition pattern (STP) for barium-paste-coated cookie swallows for three age groups. CSTP (continuous movement of the test bolus through the oropharynx without visible hesitation between the oral and pharyngeal stages of swallowing), ISTP (interrupted movement of the test bolus through the oropharynx with visible hesitation of the bolus between the oral and pharyngeal stages of swallowing).

Further analysis revealed significant differences in stage transition pattern (STP) between Groups 1 and 2 (χ^2 = 16.94858, df = 1, n = 54, $p \leq .05$) and Groups 1 and 3 (χ^2 = 11.35674, df = 1, n = 49, $p \leq .05$). There were no significant differences in STP for solid swallows between the two oldest groups (χ^2 = 0.45784, df = 1, n = 53, $p \leq .05$). For 1 df, a chi-square value of 3.841 was required for significance at the .05 level.

Intrajudge Reliability

Intrajudge reliability in identification of the seven swallowing events during the initial and repeat data analysis was high for liquid (r = 0.93) and solid swallowing measurements (r = 0.99). The coefficient of determination was 0.86. For oral bolus position, 100% agreement between the first and second analysis was obtained for each of the three judges. For stage transition pattern, 100% agreement between the first and second analysis was obtained for two of the three judges. For the third judge, agreement between the first and second analysis was 89%.

For the five temporo-spatial swallowing events, the average intrajudge difference in scoring between the first and second analysis was 0.1 s or less in 94% of the swallows. Differences greater than 0.1 s were observed in the two nonbolus events: hyoid begins maximum excursion (M = 0.39 s) and hyoid returns to rest (M = 0.13 s). Complete agreement between the first and second analysis was observed for each of the three judges for the three bolus events: (a) posterior bolus movement begins, (b) head of bolus reaches ramus, and (c) bolus tail passes through the UES.

Interjudge Reliability

Interjudge reliability in identification of the seven swallowing events was high for comparison of liquid (r = 0.97) and solid (r = 0.99) swallowing measurements. The second analysis was used to determine interjudge scoring reliability. For the two morpho-physiologic variables, 100% agreement was obtained among the three judges in oral bolus position before swallow initiation and pattern of stage transition. For the five temporo-spatial oropharyngeal swallowing events, 92% agreement (0.1 s or less) was obtained among the three judges.

Interjudge disagreement (> 0.1 s) was observed for two nonbolus durations: hyoid begins maximum excursion (M = 0.15 s) and hyoid returns to rest (M = 0.13 s). Disagreement was also observed for one bolus duration: bolus begins posterior movement (M = 0.13 s). Scoring differences greater than 0.1 s were not observed for two of the remaining three bolus durations: head of bolus reaches ramus and bolus tail passes through the upper esophageal sphincter.

For the first analysis, the average level of confidence in data collection for the three judges was 3.8, on a scale ranging from 1 (not confident) to 5 (very confident). For the repeat analysis, the average level of confidence in data collection for the three judges was 4.4.

Qualitative Observations

General qualitative observations were made for each subject in five different areas: (a) premature bolus spillage, (b) bolus residue in hypopharynx or valleculae post swallow, (c) penetration--entry of the test bolus into the laryngeal vestibule above the level of the true vocal folds, (d) aspiration--entry of the test bolus into the trachea below the level of the true vocal folds, and (e) multiple swallows required to clear the bolus from the oropharyngeal channel. Frequencies of qualitative observations noted during at least one of three swallow events for liquid and solid textures were tabulated (Table 9) and illustrated (Figures 7 and 8). With data from the groups combined, trace residue in the hypopharynx or valleculae post swallow was the most frequent observation for both liquids (73%) and solids (73%). Premature spillage was observed in 40% of liquid swallows but only 6% of solid swallows. Bolus penetration was more likely to occur in liquid swallows (27%) than solid swallows (6%). Percentage of multiple swallows was 50% (solids) and 37% (liquids).

Table 9: Frequency of qualitative oropharyngeal swallowing events observed during liquid and solid swallows in adults of different ages.

Event	Age Group		
	50-55	60-65	70-75
Premature spillage			
Liquids	4	4	4
Solids	2	0	0
Trace residue			
Liquids	8	7	7
Solids	7	8	7
Penetration			
Liquids	1	4	3
Solids	0	1	3
Aspiration			
Liquids	0	0	0
Solids	0	0	0
Multiple swallows			
Liquids	4	2	5
Solids	4	4	7

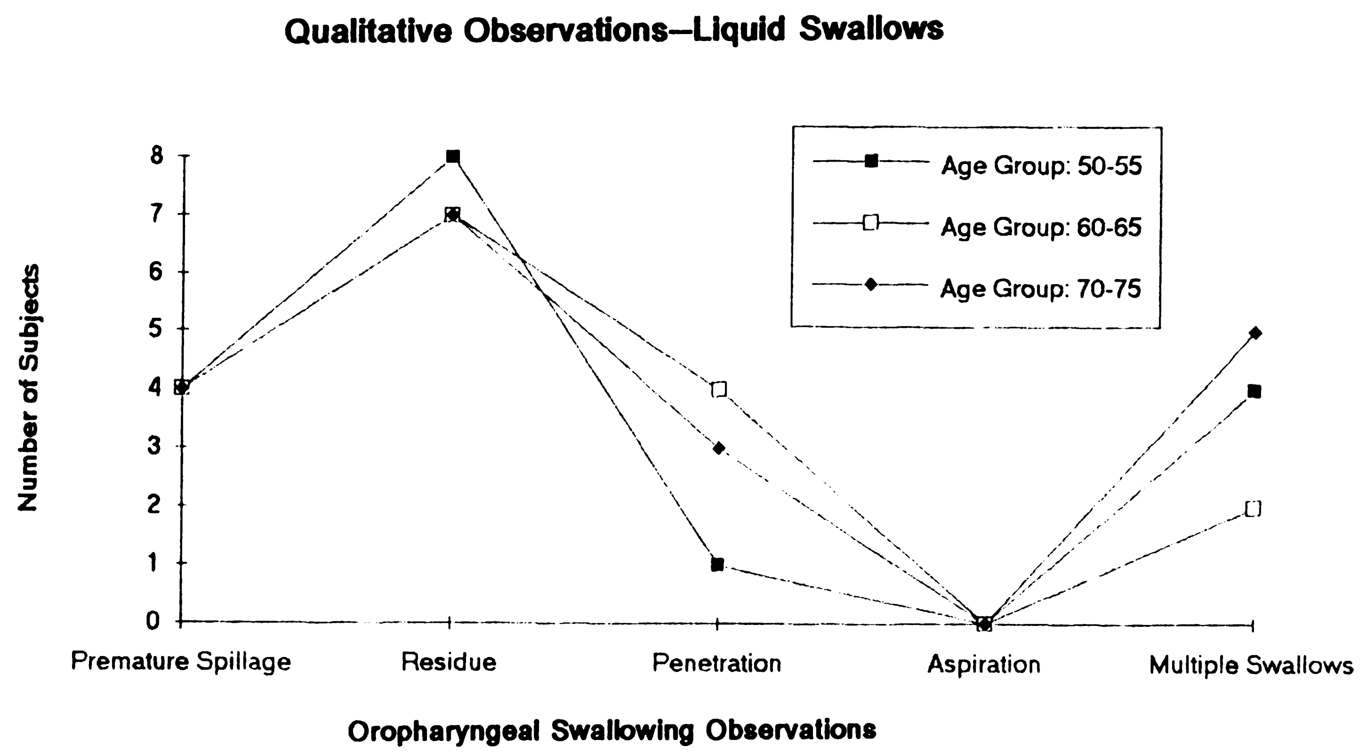

Figure 7: Frequency of qualitative oropharyngeal swallowing observations for 5 cc liquid barium swallows for three age groups.

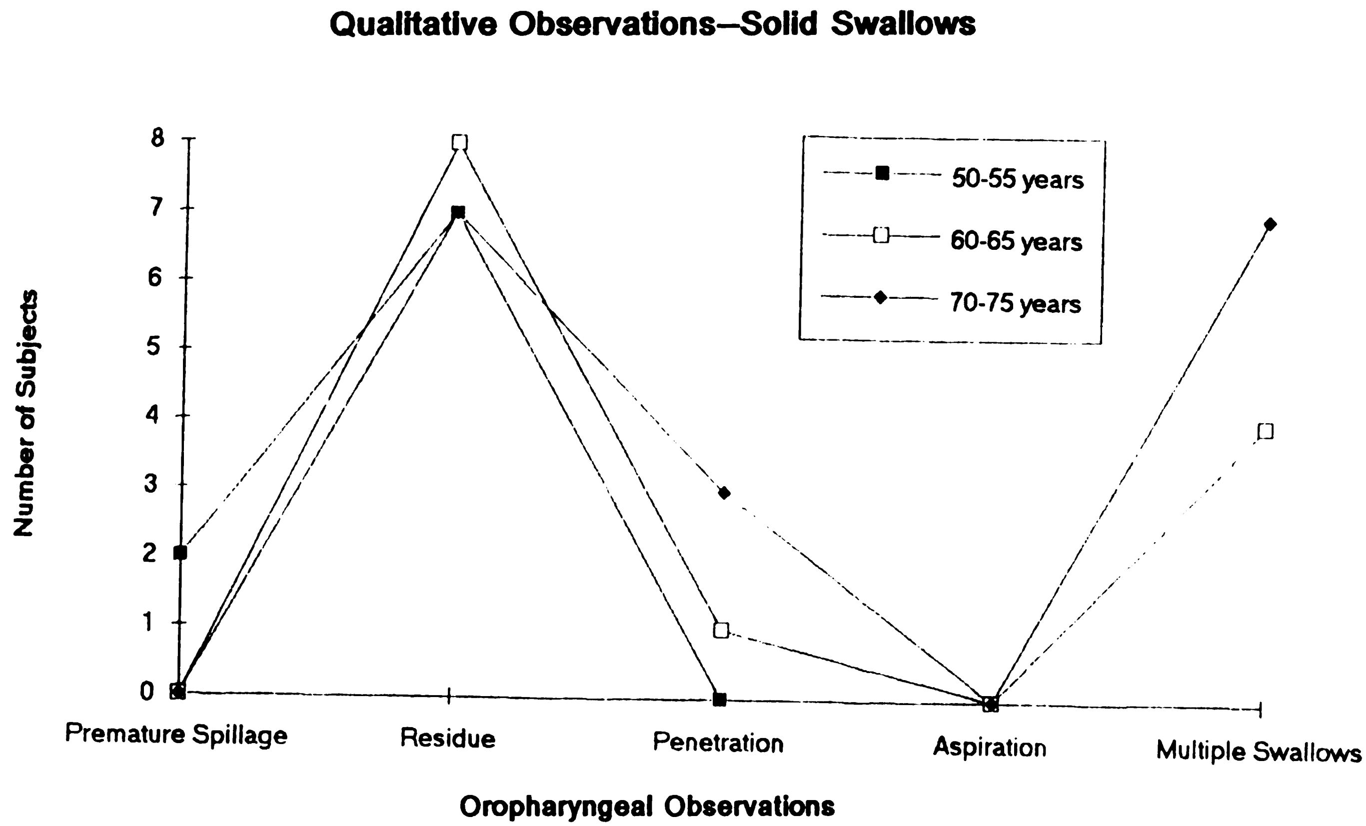

Figure 8: Frequency of qualitative oropharyngeal swallowing observations for barium-paste-coated cookie swallows for three age groups.

CHAPTER V

DISCUSSION

Summary of Results

This cross-sectional descriptive study sought normative data for investigating systematic differences in oropharyngeal swallow function in adult men over age 50. Thirty healthy adults, age 50 to 75, completed a Health History Questionnaire (HHQ), Dysphagia Screening Instrument (DSI), and Videofluoroscopy Swallow Study (VFSS) to determine whether significant differences in age-related swallow function exist.

Videofluoroscopy--the primary instrumental procedure used by speech-language pathologists providing clinical services to individuals with swallowing disorders--was the diagnostic tool of choice. The use of videofluoroscopy in this study allowed for assessment of discriminating elements of the oropharyngeal swallow: duration of bolus transit, pattern of tongue movement during oral transit, pattern of bolus positioning, pattern and duration of stage transition, and duration of hyoid movement. In the Videofluoroscopy Swallow Study, participants completed three liquid barium swallows and three barium-paste-coated cookie swallows. Measures of oropharyngeal swallowing durations and events were obtained and analyzed to determine whether differences existed among the three age groups.

There were no statistically significant differences among the three groups in the five oropharyngeal swallowing duration measures examined in this study. The findings applied to both textures: liquid barium and barium-paste-coated cookie swallows.

When the coupling between the oral and pharyngeal stages of swallowing was investigated, statistically significant differences were found between the youngest group and the two older groups in stage transition pattern for both liquid and solid swallows. Differences were also found between the youngest and oldest group in oral bolus position for liquid swallows but not for solid swallows.

Oropharyngeal Swallowing Measures

The mean bolus durations--oral transit duration, pharyngeal transit duration, and total oropharyngeal swallowing duration--for liquid swallows were similar in the three age groups. There were no statistically significant differences among the three groups.

There was no effect due to age in oral transit duration, similar to the findings of Dejaeger et al. (1994), Robbins et al. (1992), and Tracy et al. (1989). Peripheral and central recognition of food in the mouth and the primary motoric action of bolus propulsion into the oropharynx appeared to reflect a stable process of forward and upward phases of tongue base and vertical hyoid movement. The oral bolus propulsive forces appeared to get the support of the labial and velopharyngeal valves necessary for development of a positive pressure gradient for timely oral stage events.

Dejaeger et al. (1994) reported that neither the tongue-driving force generated in the oropharynx by the tongue and pharyngeal walls nor the oropharyngeal propulsion pump was significantly different in the older subjects studied, aged 75 to 85. Thus, one would argue that oral transit duration for simple liquids and solids is constant across age groups in men over 50, based on the stability of oral propulsive forces and the concept that bolus propulsion occurs as a result of a stable synergistic action of tongue thrust and hypopharyngeal negative pressure (McConnel, 1988).

Aging oral swallowing events do not appear slower or less coordinated, and sensori-motor integration would likely be adequate for timely oral bolus transit in men between the ages of 50 and 75 with normal swallowing. This agrees with the findings of Ekberg and Feinberg (1991), who reported oral sensori-motor incoordination in only 3% of adults aged 72 to 93 years. Furthermore, age-dependent alterations in oral morphology, saliva production, and chemosensory perception do not appear to impact on oral stage bolus duration measures.

For the oral bolus position observations, the oldest group in this study initiated liquid swallows with the bolus head placed posteriorly on the tongue blade significantly more often (48%) than the youngest group (22%). Oral bolus position for solid swallows did not reach statistical significance. The observation of a more posterior bolus "hold" position was also made in an earlier study (Tracy et al., 1989).

Bolus position prior to initiation of the oral stage may have had an impact on oral transit duration (OTD). In this study, OTD was measured from the beginning of posterior bolus head movement on the tongue; therefore, OTD for liquids would be expected to be shorter when the bolus is carried posteriorly, as compared with bolus carriage more anteriorly in the oral cavity. In contrast, OTD was not statistically different among the three age groups.

Perhaps oral transit duration does increase with age, as suggested by Shaw et al. (1990); but because the bolus had less distance to travel in the oral cavity with posterior placement for the oldest subjects in this study, the increased duration was not observed. This would lead one to question the presence of slower aging oral systems in nondysphagic men over age 70.

Oral bolus position for solids failed to show an age effect. Solid boluses were more often carried mid-tongue prior to initiation of the oral stage and less often carried on the posterior tongue surface. The oral stage was initiated with the bolus on the superior surface of the tongue for all swallows for all subjects, characteristic of the "tipper-type" swallow described by Dodds et al. (1989).

For pharyngeal bolus duration measures, pharyngeal transit duration (PTD) was not influenced by age in this study, similar to the findings of Dejaeger et al. (1994), Lof and Robbins (1990), and Shaw et al. (1990). Findings were similar for both liquid barium and barium-paste-coated cookie swallows. Although Robbins et al. (1992) found significantly longer PTDs and total swallowing durations in subjects over age 70 when smaller liquid bolus volumes were swallowed, the continuum of swallowing decline predicted to occur in subjects over age 45 was not observed in this study.

Stage transition duration--the interval between arrival of the bolus head at the ramus and initiation of maximal hyoid excursion--was not significantly different among the three age groups, similar to the findings of Lof and Robbins (1990). In contrast, other studies have found increased stage transition delay (Robbins et al., 1992) and pharyngeal delay (Tracy et al., 1989) among older groups.

Mean stage transition duration (STD) values for liquid swallows were negative for all groups, suggesting that hyoid excursion begins prior to arrival of the bolus at the base of the tongue. Mean STD values for solid swallows were negative for Groups 1 and 3 but positive for Group 2 ($\underline{M}$ = 0.03 s). For Group 2, mean STD was one videoframe away from simultaneous arrival of the bolus head at the ramus and initiation of maximal hyoid excursion.

From these findings, one might expect pharyngeal response--as measured by hyoid activity--to remain timely in the population of healthy, nondysphagic adult men over age 50. This is further supported by the findings associated with hyo-laryngeal response duration (HLD): no differences among age groups were found. HLD was the longest event for liquid swallows, exceeding all bolus duration measures. For solid swallows, HLD approximated total oropharyngeal swallowing duration for the two youngest groups. In the oldest group, total swallowing duration exceeded HLD.

Some investigators have defined the entire oropharyngeal phase of swallowing by the motions of the hyoid bone (Ekberg, 1986; Sonies et al., 1988). The Sonies et al. study used ultrasonography to examine 10 cc liquid swallows.

Mean hyoid activity for subjects aged 54 or less (M = 1.43 s women, 1.49 s men) was similar to the values for hyo-laryngeal response duration in this study. However, duration of hyoid activity for subjects over age 55 in the Sonies et al. study exceeded hyo-laryngeal response duration values obtained in this study by 1.0+ s.

The findings of this study suggest that the sequence of intricate neuromuscular events associated with bolus transport through the pharynx reflects a coordinated sensori-motor effort that remains relatively intact in adult men between the ages of 50 and 75. In turn, one might hypothesize that the central swallowing pathway--the dorsal region of the medulla that activates the process of swallowing and the ventral region that transmits the motor response--performs in a relatively stable and unheralded fashion when speed of swallowing is investigated.

In discussing these results, one must consider the statement by Ergun and Miskovitz (1992) that "aging itself does not cause any clinically evident dysphagia, however, age-related changes may aggravate pre-existing swallowing problems" (p. 58). It would appear that age-related changes reported by researchers in previous swallowing studies may be a product of increased vulnerability of sensori-motor systems in the presence of subtle disease states or medically compromised conditions that were previously undetected.

When stage transition pattern was investigated, a continuous pattern of stage transition was observed more frequently in the youngest group for both liquid and solid boluses. An interrupted stage transition pattern of bolus flow was more prevalent in the two older groups. This suggests that the transition between the oral and pharyngeal stages of swallowing may be qualitatively judged as uniquely demarcated, perhaps not so closely coupled in the normal swallow of adult men over age 60. When durations were not the focus of study, the sequence of involuntary, highly coordinated neuromuscular events that occurred to draw the pharyngeal wall upward over the bolus appeared to do so later in older individuals, a coordination that likely represents a natural compensatory mechanism of the aging swallow mechanism to adjust to the incoming bolus.

In clinical practice, increases in stage transition duration (STD) have been equated with (a) delayed onset of pharyngeal dynamics, (b) delayed triggering of the swallow reflex, and (c) pharyngeal swallow delay. Qualitative judgments of swallow delay or "stage transition pattern" may not be the best indicator of actual delay in the onset of the pharyngeal swallow, as observed by the mean STD values obtained on the Videofluoroscopy Swallow Study. There were no significant differences among groups in STD in this study. Observations of stage transition pattern might correspond more closely with STD when measured at the onset of anterior excursion in future studies.

Qualitative Observations

The videofluoroscopy results in the clinical sample suggest that duration measures for liquids and solids are fairly constant in men between the ages of 50 and 75. In this study, several qualitative oropharyngeal swallowing observations were made; some of these events would be judged by many professionals as abnormal activity (e.g., penetration, residue). Other researchers have made similar nondurational observations. Ekberg (1982) observed swallowing aberrations in 17% of nondysphagic individuals of all ages, with penetration present in 6% of the subjects. Liquid penetration was observed in 27% of the subjects in this study, only 10% of which occurred in the youngest group. Vallecular and diffuse hypopharyngeal residue post swallow was subjectively rated as present in 73% of the subjects. Although residue could not be quantified using videofluoroscopy in this study, Cook et al. (1994) found that pharyngeal post-swallow residual counts increased significantly with age.

Pharyngeal contraction has a significant function in pharyngeal clearing, with residue minimized when adequate tongue-driving forces and pharyngeal shortening exist. Kahrilas (1993) summarized two important components of deglutive pharyngeal contraction: longitudinal shortening and propagated horizontal contraction. Pharyngeal shortening has the effect of approximating the upper esophageal sphincter to the tongue base. Adequate pharyngeal shortening obliterates the laryngeal vestibular pyriform recesses, thus minimizing post-swallow residue. In contrast, horizontal contraction coincides with clearance of the bolus tail through the pharynx, acting as a pharyngeal clearance mechanism.

Observations on the pharyngeal clearing mechanism in this study suggest that bolus clearance may not be as efficient as that of younger subjects. In addition, the occurrence of multiple swallows for liquids ($\underline{n}$ = 11) and solids ($\underline{n}$ = 12) is not surprising. This observation, coupled with the presence of liquid penetration by eight subjects, might suggest that the pharyngeal clearance mechanisms of longitudinal and horizontal contraction might be compromised in the older subject; and increased pharyngeal residue is a characteristic swallowing feature in nondysphagic men over age 50.

Clinical and Research Implications

Potential Limitations in Aging and Swallowing Research

Identification of normal swallowers is a difficult task in research on aging and deglutition. Most researchers of aging and swallowing eliminate subjects from their study who have compromising medical conditions or diseases known to influence deglutition (Dejaeger et al., 1994; Lof & Robbins, 1990; Sonies et al., 1988; Tracy et al., 1989). Others eliminated subjects who were asymptomatic for dysphagia (Ekberg & Feinberg, 1991) regardless of medical history.

In this study, detailed efforts were made to determine the presence of compromising medical conditions to eliminate threats to internal validity. No participants had a documented medical, surgical, or medication history found to interfere with oropharyngeal swallowing. This information was confirmed by the attending physician on the medical chart. The Health History Questionnaire further ruled out the presence of compromising conditions as reported by the subjects themselves. Speech and voice difficulties were also not a factor in any of the subjects.

However, one must consider the fact that the medical history of the subjects may not have been thoroughly representative of all possible conditions that could potentially influence normal swallowing. Knowledge of dysphagia and conditions associated with deglutition problems are continuously expanding. There is always the possibility that subtle conditions associated with swallowing performance went undetected.

Furthermore, the subject's self-knowledge of medical conditions may have been a limiting factor. The participants (a) may not have been aware of previously diagnosed conditions, (b) may have been confused about the definition or description of a medical condition, or (c) may have been unsure of the presence or absence of a condition, therefore stating "no" to the investigator's health history questions when in fact they might have responded "yes."

Even though there may have been conditions that went undetected, it is thought that the male participants in this study represented a population of healthy adults. Furthermore, the participants in this study likely represented men between the ages of 50 and 75 whose swallowing would be considered normal. Future studies of aging and normal swallowing will need to include specific and detailed procedures aimed at ruling out potential medical conditions as well as pharmacological effects that might interfere with the normal swallowing process.

To identify normal swallowers, researchers of aging and swallowing should implement use of a reliable and valid swallowing screening tool to further support the notion of normal swallowing. In this study the sensori-motor tasks on the Dysphagia Screening Instrument (DSI) focused on the presence of normal structure and function in lingual, labial, and laryngeal systems.

In one prior study, researchers of aging and swallowing used an oral-motor evaluation and swallowing screening to rule out subjects with deglutition problems (Sonies et al., 1988). A surprising number of researchers did not describe the oropharyngeal sensori-motor exam used (Lof & Robbins, 1990) or failed to include a clinical screening tool to rule out the presence of dysphagia in their subjects (Dejaeger et al., 1994; Ekberg & Feinberg, 1991; Tracy et al., 1989; Wilson et al., 1990). Rather, they simply reported the fact that no subjects had a history of dysphagia.

In one study comparing clinical signs of dysphagia with videofluoroscopy findings of aspiration (Linden, Kihlemeier, & Patterson, 1993), nine clinical signs were associated with subglottic penetration, all of which were associated with laryngeal functioning. The authors found that the probability of correctly predicting subglottic penetration from clinical observations was approximately 66%.

The Dysphagia Screening Instrument used in this study contained seven task items associated with laryngeal functioning. Four tasks were similar to those described by Linden et al. (1993): voluntary cough (spontaneous cough quality), laryngeal elevation (laryngeal elevation), vocal quality (wet phonation), and saliva control (swallowing of secretions). There is the possibility that this screening instrument failed to detect or predict subtle swallowing deviations involving the pharyngeal stage. This is especially important considering the presence of penetration in eight (27%) of the subjects in this study.

The Dysphagia Screening Instrument contained six items sensitive to lingual functioning. Considering the nature of the investigation which addressed both durational and nondurational measures of oral stage swallowing, these items appeared critical to the study at hand. If one considers McConnel's (1988) model of swallowing as a two-pump system, tongue compression against the pharyngeal wall is essential in the development of positive pressure applied to the bolus. The peripheral and central recognition of food in the mouth and the lingual motor response are key elements in successful initiation of the swallow, and any screening tool that fails to address primary lingual control would be inadequate.

The Dysphagia Screening Instrument was administered to each subject by the principal investigator only once. No other judges were involved in the screening process. To eliminate threats to internal validity and establish reliability data, a repeat analysis by the principal investigator and a separate analysis by an additional judge would be warranted in future studies.

Considering the importance of the screening process in studies of normal swallowing, the Dysphagia Screening Instrument developed for use in this study appeared sensitive enough to identify potential swallowing alterations in the participants in this study. No significant differences among age groups were found across six factors.

Delay from completion of the Dysphagia Screening Instrument (DSI) to completion of the Videofluoroscopy Swallow Study (VFSS) averaged 11 days. The screening process averaged 20 minutes for each subject. The VFSS procedure, including waiting time and videotape review, averaged 30 minutes. There is the possibility that history confounded the effects of the oropharyngeal swallowing variables on the VFSS in some of the subjects. A change in the subjects' swallowing status may have occurred between the administration of the DSI and the VFSS. Or changes in psychological and physiological status may have confounded the effects. In future studies, the shorter the interval between the screening and the actual swallow study, the lesser the likelihood that history will serve to contaminate the results.

Swallowing Measures

From this study, several important swallowing measures have been identified that can be used in clinical practice. First, it is reasonable to assume that duration values for small liquid and solid boluses remain relatively constant in the population of adult men between age 50 and 75. As a baseline, the clinician would expect healthy adults to (a) transport a 5 cc liquid bolus through the oropharynx in 1.0 s or less on average; (b) transport a small solid bolus through the oropharynx in 1.30 s or less on average; (c) demonstrate hyoid durations of 1.3 s on average for liquid and solid bolus swallows; (d) be less likely to demonstrate a smooth and continuous transition pattern between the oral and pharyngeal stages of swallowing with advanced age; (e) occasionally demonstrate premature spillage, residue post swallow, and penetration of liquids as a normal condition of swallowing; and (f) occasionally demonstrate multiple swallows and hypopharyngeal residue post swallow for masticated boluses.

Future studies of oral stage events should involve detailed investigation of barium-impregnated and masticated foods. Specifically, studies involving larger bolus volumes, "bolus sectioning," and oral preparatory maneuvers would provide insight into timing and patterns of bolus management in the oral cavity.

To further understand the pharyngeal stage, additional studies need to focus on refining measurement of stage transition duration or "pharyngeal delay," delineate the role of pharyngeal contraction in individuals with poor vallecular clearing, and determine the nature of qualitative differences in pharyngeal clearing that may exist in asymptomatic older individuals. Research on aging and normal swallowing should also examine the ability to perform dynamic swallowing maneuvers frequently utilized by practicing clinicians.

Subject Selection

The writer acknowledges that "normal" in this clinical sample is defined solely by the group of normal male controls selected and does not imply a normal pattern of swallowing among all asymptomatic individuals over age 50. It does suggest, however, that the range of normalcy is perhaps broader than expected; and judges may mistake "normal" swallowing events in older individuals as abnormal swallowing events. The 30 participants in this study likely represented men between the ages of 50 and 75 whose swallowing would be considered normal. However, larger sample sizes would be warranted in future studies of normal swallowing.

All participants in this study were men. Although women were not excluded from this study, few women in the age range specified were identified, and no women in the age range of 50 to 75 years met the criteria for inclusion. Further investigations may want to include women to measure gender differences in oropharyngeal swallowing events.

Identification and Assessment

Further refinement of screening tools and noninstrumental evaluation techniques would be warranted in future studies of normal and disordered swallowing. Researchers of aging and swallowing should implement a screening tool similar to the Dysphagia Screening Instrument to further support the notion of normal swallowing. Quantitative and qualitative measures of normal oropharyngeal swallowing must be systematically studied in older individuals to strengthen the clinician's skills in differentiating between normal and abnormal swallowing.

A heightened awareness of normal swallowing by practitioners may result in early identification of symptoms or warning signs, which in turn may prevent decline in swallowing among older institutionalized individuals. Specifically, enhanced knowledge may eliminate the risk for developing swallowing disorders often associated with specific disabilities affecting many older adults: incontinence, immobility, malnutrition, dehydration, intellectual impairment, instability, or generalized debility.

Clinical Management

Knowledge of videofluoroscopy findings in asymptomatic, normal swallowers will enable practicing clinicians to use this diagnostic technique to more effectively manage patients who aspirate or have primary clinical conditions of oropharyngeal dysphagia. Clinical advances associated with heightened knowledge of neuromuscular function and sensori-motor integration in the normal swallow would include improved application of diagnostic and therapeutic principles to individuals with a broad spectrum of dysphagic characteristics. Clinical advances should be realized in identification of risk factors, establishment of therapeutic protocols (e.g., neuromuscular facilitation, compensatory strategies, swallowing maneuvers), and evaluation of clinical outcomes.

In working with adults with oropharyngeal dysphagia, practicing clinicians are obligated to advance their techniques beyond simple diet modifications and positioning recommendations. The application of systematic yet person-centered approaches should enhance clinical outcomes.

Clinical outcomes of institutionalized older adults with dysphagia are not promising. In a study of 12-month outcomes on 22 nursing home residents with aspiration identified on videofluoroscopy (Croghan, Burke, Caplan, & Denman, 1966), 68% required feeding tube placement, 82% were rehospitalized, 50% developed pneumonia, and 50% expired. The residents who underwent videofluoroscopy had poor clinical outcomes at 12 months, regardless of test results. The clinical practitioner cannot ignore these findings or sidestep the challenge they impose.

Prevention of swallowing decline in older individuals entails adaptation of a "quality-of-life" standard. To improve quality of life for institutionalized adults, practicing clinicians would be trained to (a) reference normative data on the timing and duration of oropharyngeal swallowing events in clinical practice, (b) identify risk factors associated with dysphagia, (c) utilize technically advanced diagnostic methods and specific protocols for assessment of swallowing performance, (d) design environments conducive to optimal oral intake, (e) educate caregivers and professionals working with older adults in a knowledge base consistent with an understanding of the fundamentals of normal swallowing, and (f) maximize functional independence in all aspects of eating and swallowing.

APPENDICES

APPENDIX A

VA RESEARCH CONSENT FORM 10-1086

Department of Veterans Affairs

VA RESEARCH CONSENT FORM

Subject Name: ______________________ **Date** ____________

Title of Study: The Effects of Aging on Selected Parameters of Oropharyngeal Swallowing

Principal Investigator: Debra Gleeson, M.A., CCC-SLP Ph.D. Candidate, MSU **VAMC:** Battle Creek, MI

DESCRIPTION OF RESEARCH BY INVESTIGATOR

1. **Purpose of study and how long it will last:**
2. **Description of the study including procedures to be used:**
3. **Description of any procedures that may result in discomfort or inconvenience:**
4. **Expected risks of study:**
5. **Expected benefits of study:**
6. **Other treatment available:**
7. **Use of research results:**
8. **Special circumstances:**

PURPOSE OF STUDY: There has been minimal research on the functions of the swallowing mechanism in adults over age 50. We do not know for sure if swallowing becomes more difficult or slows down with age, or if, in fact, the process of swallowing remains normal into old age. As a result, this study is designed to examine the effects of aging on the ability to swallow in 45 normal, healthy adults ranging in age from 50 to 75 years. By learning about the normal aspects of swallowing in the older population, knowledge of normal and abnormal swallowing may be further realized, allowing for effective medical and therapeutic management of persons with disorders of swallowing (dysphagia).

DESCRIPTION OF STUDY AND PROCEDURES: This study involves completion of three distinct steps. STEP 1, completion of a Health History Questionnaire, requires you to answer questions about your medical, surgical, speech, voice and swallowing history. STEP 2, the Dysphagia Screening Protocol, will be completed to examine your swallowing mechanism and rule out the presence of swallowing difficulty. It involves an examination of your tongue, lips, mouth, and throat. You will be asked to perform simple tasks, such as cough, swallow, and move your tongue back and forth. STEP 3 involves completion of a Videofluoroscopy X-ray (radiation) Procedure to examine your swallowing mechanism. You will be required to swallow small amounts of liquid barium and a barium-coated cookie. The Chief of Radiology will take videofluoroscopy x-ray pictures of your oral cavity and throat. The principal investigator and two additional certified speech-language pathologists trained in analyzing fluoroscopy x-ray pictures will then examine the video pictures to take measurements of your swallowing pattern.

SUBJECT'S IDENTIFCATION (I.D. plate or give name-last, first, middle)

Department of Veterans Affairs

VA RESEARCH CONSENT FORM
(Continuation Page 2 of 4)

Subject Name: ______________________ **Date** ____________

Title of Study: The Effects of Aging on Selected Parameters of Oropharyngeal Swallowing

Principal Investigator: Debra Gleeson, M.A., CCC-SLP Ph.D. Candidate, MSU **VAMC:** Battle Creek, MI

DISCOMFORTS/RISKS: Participation in this study is not expected to cause psychological or physical discomforts; however, some people may find the questions or procedures unpleasant or inconvenient. Specifically, you may find the taste of the barium to be unpleasant. Adverse reactions and/or allergic reactions after ingestion of the barium are infrequent and usually mild. Mild allergic reactions include rash and itching. Rare severe reactions (1 in 500,000) include shortness of breath (bronchospasm), low blood pressure (hypotension), and swelling of the throat (laryngeal edema). Death (1 in 2,000,000) has been reported. Other side effects to the barium may include constipation, cramping, or diarrhea. Because the amount of barium you swallow will be very small (i.e., 2 tablespoons), the likelihood of inhaling the barium substance into your lungs (aspiration) or experiencing adverse reactions is rare. Upon completion of this procedure, there will be no restrictions on normal activities.

As a precautionary measure, you will not be allowed to participate in this study if you have (1) a known obstruction of the colon, (2) a suspected or impending gastrointestinal perforation, (3) a known hypersensitivity to barium sulfate products, (4) bronchial asthma, (5) a history of multiple (greater than three) food or drug allergies, (6) a history of allergies as evidenced by hayfever and eczema, or (7) used medications that contain a topical anesthetic agent like those in mouthwashes (i.e., Listerine), sore throat products (i.e., Cepacol, Vicks, Cepastat and Chloraseptic), cough medicines, or products for tooth or gum pain (i.e., Orajel, Orabase, Anebesol) within one to two hours prior to participation in the videofluoroscopy x-ray procedure.

High doses of radiation and long-term radiation exposure have been associated with the development of some malignancies and contribute to overall lifetime cancer risk. According to the Chief of Radiology, there are no immediate complications or conceived risk of long-term complications associated with radiation exposure from the videofluoroscopy x-ray procedure. The radiation exposure will be significantly less than that obtained from a common chest x-ray. Total duration of radiation exposure from the videofluoroscopy x-ray procedure will not exceed five minutes and will most likely be less than two minutes.

BENEFITS: Identification of the aging characteristics of swallowing may not directly benefit you, but may benefit health professionals working with older adults. Through the knowledge gained from understanding the aging swallow, guidelines for assessment, treatment and management of adults with swallowing disorders can be developed, strengthened, and implemented.

Department of Veterans Affairs

VA RESEARCH CONSENT FORM
(Continuation Page 3 of 4)

Subject Name: ________________________ **Date** ____________

Title of Study: The Effects of Aging on Selected Parameters of Oropharyngeal Swallowing

Principal Investigator: Debra Gleeson, M.A., CCC-SLP Ph.D. Candidate, MSU **VAMC:** Battle Creek, MI

PARTICIPATION/RIGHTS: Physician's consent will be obtained prior to your participation in this study. Participation in this study can be completed in one or two sessions. The total amount of time required for participation in the study is estimated to be 45 minutes to one hour.

I am aware that participation in this study is voluntary, and I may withdraw from participation at any time. I will not be paid for participation in this study, nor will I be responsible for the costs associatd with the study. I am aware that all results will be treated with strict confidence. Video pictures presented to outside judges will not be identified by subject. I will remain anonymous in any report of research findings, and I will not be associatd with any specific respnses or other data. At my request, research findings may be made available to me.

If you sustain any injury related to your participation in this study, you are entitled to any necessary care and treatment. Compensation may also be payable pursuant to Federal Law under Title 38 U.S. Code, Section 1151, or in some circumstances under the Federal Tort Claims Act.

If I have any questions regarding my rights as a research subject, Tina Maloney, Pharm.D., Chairperson of the Subcommittee on Human Studies, can be contacted at (616) 966-5600, Ext. 4001.

Department of Veterans Affairs

VA RESEARCH CONSENT FORM

(Continuation Page 4 of 4)

Subject Name: ____________________ **Date** ____________

Title of Study: The Effects of Aging on Selected Parameters of Oropharyngeal Swallowing

Principal Investigator: Debra Gleeson, M.A., CCC-SLP Ph.D. Candidate, MSU **VAMC:** Battle Creek, MI

RESEARCH SUBJECTS' RIGHTS: I have read or have had read to me all of the above. Debra Gleeson, M.A. has explained the study to me and answered all of my questions. I have been told of the risks or discomforts and possible benefits of the study. I have been told of other choices of treatment available to me.

I understand that I do not have to take part in this study, and my refusal to participate will involve no penalty or loss of rights to which I am entitled. I may withdraw from this study at any time without penalty or loss of VA or other benefits to which I am entitled.

The results of this study may be published, but my records will not be revealed unless required by law.

In case there are medical problems or questions, I have been told I can call the Medical Officer of the Day (MOD) at (616) 966-5600, Ext. 0 (Operator) during the day and the MOD at same number after hours. If any medical problems occur in connection with this study the VA will provide emergency care.

I understand my rights as a research subject, and I voluntarily consent to participate in this study. I understand what the study is about and how and why it is being done. I will receive a signed copy of this consent form.

Subject's Signature	Date
Signature of Subject's Representative*	Subject's Representatives
Signature of Witness	Witness (print)
Signature of Investigator	

*Only required if subject not competent.

IF MORE THAN ONE PAGE IS USED, EACH PAGE (VAF 10-1086A) MUST BE CONSECUTIVELY NUMBERED AND SIGNED.

APPENDIX B

HEALTH HISTORY QUESTIONNAIRE

HEALTH HISTORY QUESTIONNAIRE

SUBJECT:______________________________ DATE:________________
BIRTHDATE:____________________________ AGE:_______ SEX:_______

Instructions to be read by the Principal Investigator:

"I am going to ask you some questions about your health history. I will read each question carefully to you and you are to answer each question with a YES or NO. If you do not know, I will check with your physician and your medical records to determine the correct answer. If you do not understand the question or need me to repeat or explain the question, be sure to let me know. Do you have any questions? Let's begin."

A. Regarding your medical history, do you presently or have you ever had...

1.	Alzheimer's disease	Yes____	No____
2.	Amyotrophic lateral sclerosis	Yes____	No____
3.	Aspiration pneumonia	Yes____	No____
4.	Bronchial asthma	Yes____	No____
5.	Cancer of the mouth, throat, or esophagus	Yes____	No____
6.	Cerebral palsy	Yes____	No____
7.	Cervical spur	Yes____	No____
8.	Cleft lip or palate	Yes____	No____
9.	Colon obstruction	Yes____	No____
10.	Dermatomyositis	Yes____	No____
11.	IDDM or NIDDM	Yes____	No____
12.	Dysphagia (difficulty swallowing)	Yes____	No____
13.	Encephalitis	Yes____	No____
14.	Esophageal reflux, rings, webs, or esophagitis	Yes____	No____
15.	Food or drug allergy (more than 3)	Yes____	No____
16.	Friedreich's ataxia	Yes____	No____
17.	Gastrointestinal perforation	Yes____	No____
18.	Guillain-Barre syndrome	Yes____	No____
19.	Head trauma (or TBI)	Yes____	No____
20.	Heart attack	Yes____	No____
21.	Hiatal hernia	Yes____	No____
22.	Huntington's chorea	Yes____	No____
23.	Hypersensitivity to barium sulfate	Yes____	No____
24.	Inflammation of the epiglottis	Yes____	No____
25.	Lupus	Yes____	No____
26.	Meningitis	Yes____	No____

27. Multiple sclerosis Yes____ No____
28. Muscular dystrophy Yes____ No____
29. Myasthenia gravis Yes____ No____
30. Parkinson's disease Yes____ No____
31. Poliomyelitis Yes____ No____
32. Polymyositis Yes____ No____
33. Scleroderma Yes____ No____
34. Sjogren's syndrome Yes____ No____
35. Spinal cord injury Yes____ No____
36. Stroke (cerebral vascular accident) Yes____ No____
37. Thyroid hypofunction Yes____ No____
38. TIA (transient ischemic attack) Yes____ No____
39. Tumor of the head, neck or mouth Yes____ No____
40. Wilson's disease Yes____ No____
41. Xerostomia (dry mouth) Yes____ No____
42. Zenker's diverticulum Yes____ No____

Other____

B. Regarding your surgical history, have you ever had surgery involving your...

1. Brain Yes____ No____
2. Esophagus Yes____ No____
3. Face or head Yes____ No____
4. Heart Yes____ No____
5. Mouth Yes____ No____
6. Stomach Yes____ No____
7. Throat, larynx, or neck Yes____ No____

Other____

C. Regarding your speech, do you presently or have you ever had...

1. Difficulty pronouncing sounds Yes____ No____
2. Difficulty expressing ideas Yes____ No____
3. Numbness or tingling in the face Yes____ No____
4. Slurred speech Yes____ No____
5. Weakness in the facial area Yes____ No____

Other____

D. Regarding your voice, do you presently or have you ever had...

1. Extremely breathy voice Yes____ No____
2. Extremely hoarse or harsh voice Yes____ No____
3. Pain in your throat Yes____ No____
4. Periods of voice loss Yes____ No____
5. Wet/gurgly voice quality Yes____ No____

Other____

E. Regarding your swallowing, do you presently or have you ever had...

1. Choking episodes when swallowing Yes____ No____
2. Coughing episodes when swallowing Yes____ No____
3. Difficulty controlling saliva Yes____ No____
4. Difficulty swallowing liquids Yes____ No____
5. Difficulty swallowing solids Yes____ No____
6. Food leakage from mouth or nose Yes____ No____
7. Pain while swallowing Yes____ No____

Other____

F. In addition, Do you...

1. Frequently use medications that contain a topical anesthetic agent like those in mouthwashes (Listerine), sore throat products (Cepacol, Vicks, Cepastat and Chloraseptic), cough medicines, or products for tooth or gum pain (Orajel, Orabase, Anebesol)?
Yes____ No____

2. Have any other conditions or concerns you feel I should know about?
Yes____ No____

____
____
____

SUMMARY: Number of YES responses _____/68
Number of NO responses _____/68

PASS _____ FAIL _____

APPENDIX C

STRUCTURAL AND PHYSIOLOGIC DYSPHAGIA SCREENING COMPONENTS

Table C1: Structural and physiologic dysphagia screening components.

Category	Dysphagia Screening Component
Mandible	Elevation, depression Lateralization, protrusion
Lips	Sensation Retraction, protrusion Symmetry Seal, strength
Tongue	Sensation Protrusion, retraction Elevation, depression Lateralization Anterior tongue DDK Posterior tongue DDK Strength, symmetry
Palate	Sensation, symmetry Velar elevation Gag reflex
Larynx	Voluntary cough, reflexive cough, throat clearing Involuntary swallow Voluntary dry swallow Voluntary liquid swallow Laryngeal elevation
Voice	Quality Pitch Intensity Sustained phonation
Speech	Intelligibility Rate Articulation
Respiration/other	Breathing pattern Rate Saliva control Posture

APPENDIX D

DYSPHAGIA SCREENING INSTRUMENT

DYSPHAGIA SCREENING INSTRUMENT

SUBJECT:______________________________ DATE:__________________
BIRTHDATE:____________________________ AGE:_______ SEX:_______

Scoring Directions: For each task completed correctly, immediately and without cues, assign a score of "1." For each task completed incorrectly, with significant delay or with verbal/tactile cues, assign a score of "0." Total possible score is 15. Passing score is 15.

SCORE	TASK	
______	1.	**Lingual sensation**--Detect light touch applied with cotton-tipped swab to anterior 2/3 and posterior 1/3 of tongue.
______	2.	**Lingual strength**--Actively resist moderate anterior tongue tip pressure applied with tongue depressor.
______	3.	**Lingual elevation**--Touch tongue tip to upper lip and alveolar ridge.
______	4.	**Lingual lateralization**--Demonstrate full range of tongue tip movement from one corner of the mouth to the other corner.
______	5.	**Posterior tongue movement**--Elevate back of tongue to articulate /k/ 10 times in 5 seconds.
______	6.	**Lingual symmetry**--Tongue symmetrical at rest and when protruded past lips.
______	7.	**Labial seal**--Close lips tightly and hold 5 cc of water in mouth with no observable leakage.
______	8.	**Voluntary cough**--Initiate and demonstrate sharp cough and sharp glottal attack on the vowel /a/.
______	9.	**Involuntary swallow**--Observable swallow on 2 occasions within 2 minutes.
______	10.	**Voluntary dry swallow**--Initiate 3 consecutive dry swallows within 10 seconds.
______	11.	**Voluntary liquid swallow**--Demonstrate swallow of 5 cc of water within 5 seconds.
______	12.	**Laryngeal elevation**--Elevation of larynx observed and palpated during dry or liquid swallow.
______	13.	**Reflexive cough**--Absence of reflexive cough after swallowing 5 cc of water.
______	14.	**Vocal quality**--Absence of wet/gurgly voice quality during phonation of /a/ after swallowing 5 cc of water.
______	15.	**Saliva control**--No observable drool or dribble.

______ = **TOTAL SCORE** **PASS**______ **FAIL**______

APPENDIX E

VIDEOFLUOROSCOPY PROCEDURE

VIDEOFLUOROSCOPY PROCEDURE

PRINCIPAL INVESTIGATOR (PI): Debra Gleeson
RADIOLOGIST (R): Dr. Shah

EQUIPMENT REQUIRED:

1. General Electric Prestilix (Model #1690s)
2. JVC Super VHS Player/Recorder (#BR8611U)
3. Panasonic Color S-Video Monitor (#CT1383Y)
4. Panasonic Time/Date Generator (#WJ-810)
5. Rehab Tech Videofluoro Swallow Study Chair
6. Super VHS Master Broadcast Videocassette tapes

MATERIALS REQUIRED:

1. EZ paste barium sulfate cream (120% wt/vol)
2. EZPAQUE liquid barium (95% wt/vol)
3. Lorna Doone cookies
4. Plastic medicine cups

VIDEOFLUOROSCOPY RECORDINGS:

1. 70-80 KeV
2. Exposure will be limited to < 10 seconds for each test bolus and < 300 seconds for each subject
3. Distance between fluoroscopy table and tube will remain constant (< 3 feet) for each subject

FOCUS:

1. Subjects are viewed in the lateral plane
2. Visible structures include the lips, teeth, tongue, palate, velum, mandible, hyoid bone, larynx, and UES
3. Anterior margin--lips
4. Posterior margin--pharyngeal wall
5. Superior margin--hard palate
6. Inferior margin--seventh cervical vertebra

PREPARATION:

1. PI will prepare fluoroscopy materials prior to subject's arrival
2. PI will be sure recording equipment is in proper working condition and ready for recording
3. R will be sure fluoroscopy equipment is in proper working condition
4. Prior to recording, PI will code video tapes by subject number (01-15) and group membership (1 = 50-55 years; 2 = 60-65 years; 3 = 70-75 years)

LIQUID BARIUM PROCEDURES:

1. Subjects will stand or sit in Rehab Tech Videofluoro swallow study chair if physical limitations prohibit standing
2. Subjects will be asked if they used medications that contain a topical anesthetic agent like those in mouthwashes (i.e., Listerine), sore throat products (i.e., Cepacol, Vicks, Cepastat, and Chloraseptic), cough medicines, or products for tooth or gum pain (i.e., Orajel, Orabase, Anebesol) during the last 2 hours
3. PI will give 5 ml liquid barium in plastic medicine cup to subject
4. PI will instruct subject, "Put the barium in your mouth and hold it until I say **swallow**. When I say **swallow**, I want you to swallow all of the barium as normally and naturally as possible. Be sure to wait until I say **swallow**"
5. R will activate fluoroscopy at PI's command, **Ready**
6. PI will give the command to **swallow**
7. R will deactivate fluoroscopy when the bolus tail passes through the UES and at PI's command to **stop**
8. Above procedure will be repeated two more times for a total of three swallows of liquid barium

BARIUM COOKIE PROCEDURE:

1. PI will give subject 1/2 of a Lorna Doone cookie with 2 ml of barium paste coated on top
2. PI will instruct subject, "Put the cookie in your mouth and chew it up. When you are ready to swallow it, raise your hand. When I say **swallow**, go ahead and swallow the cookie as naturally and normally as possible. Be sure to wait until I say **swallow**"
3. R will activate fluoroscopy at PI's command, **Ready**
4. PI will give subject command to **swallow**
5. R will deactivate fluoroscopy when the bolus tail passes through the UES and at PI's command to **stop**
6. The above procedure will be repeated two more times for a total of three swallows of barium-paste-coated cookie

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