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The Videofluorographic Swallowing Study

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SYNOPSIS

The evidence for the physiologic foundation and interpretation of the videofluorographic swallowing study (VFSS) is described. The purpose and clinical utility of VFSS are explained. Standardization of the VFSS procedure, protocol, interpretation and reporting is highlighted as a critical step in future clinical practice and in clinical research. Individualized, evidenced –based rehabilitation strategies are presented as key components that are systematically applied during the VFSS procedure and integrated into the swallowing management plan. A new tool that has been developed and tested for the quantification of swallowing impairment is introduced.

Keywords

swallowing; dysphagia; videofluoroscopy; standardization; deglutition

INTRODUCTION

The literature is dense with measurement methods used to estimate the presence and degree of the oropharyngeal and esophageal swallowing dysfunction. These methods are directed toward gaining objective indexes of the timing [1-8], pressure [5, 9-15], range [16-18], and strength [19-21] of structural movements, bolus flow patterns [22-26], bolus clearance and efficiency [11],

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airway protection [27, 28], and sensation [29-32]. These studies have established a strong theoretical framework toward understanding the nature of swallowing abnormalities. The existence and development of multiple assessment methods in a healthcare climate of that demands fiscal responsibility, the clinician must choose the test that is appropriate for the patient and delivers the highest diagnostic and prognostic clinical yield. Further, the test and the measurement methods employed to capture oropharyngeal swallowing impairment must be practical for routine clinical application.

The videofluorographic swallowing study (VFSS), also known as a modified barium swallowing examination (MBS) is often considered the instrument of choice by the majority of practicing swallowing clinicians because it permits the visualization of bolus flow in relation to structural movement *throughout* the upper aerodigestive tract in real-time. The VFSS also permits detection of the presence and timing of aspiration, i.e., entry of ingested material through the level of the true vocal folds into the trachea [33, 34], and assists in identifying the physiologic and often treatable cause(s) of the aspiration[35-39]. Further, clinicians are able to observe the effects of various bolus volumes, bolus textures, and compensatory strategies on swallowing physiology [37].

Clinicians evaluating and treating swallowing disorders use a videofluoroscopic radiology procedure to assess swallowing physiology in patients with symptoms of swallowing disorders (i.e. dysphagia) and estimate the degree of swallowing impairment from observations made during the exam. The examination usually includes the collaborative expertise of a physician (most commonly a radiologist or physiatrist and speech-language pathologist. This procedure, the modified barium swallow (MBS) examination, captures sequential videoradiographic images of barium contrast- impregnated food and liquid as they are transported during the oral cavity, pharyngeal cavity, and esophagus in real time. Various volumes and textures of food and liquid are administered and clinical impressions of the presence and degree of swallowing impairment are obtained from the radiographic images [35, 38-43]. Judgments are also made regarding the coordination and timing of swallowing events [1, 28, 36, 44-48]. Based on these qualitative observations, critical, and sometimes life-sustaining recommendations are made regarding oral versus non-oral intake, diet type, referrals to other medical specialties, and treatment strategies that improve function or minimize the risk of aspiration [38]. Despite the clinical utility of the examination, clinicians must appreciate that the patient's performance during the exam may not be entirely representative of the patient's typical eating and drinking performance. Variables such as fatigue, medications, anxiety, etc. may impact the testing results. It is imperative that clinicians observe patients during their usual eating and drinking environment to determine the external validity of the examination results and to assess the patient's ability to carry-over any learned swallowing strategies. Further, the VFSS is also used to monitor any changes in swallowing function over time during the course of swallowing treatment, progression of a disease or condition.

VFSS: AN INDIRECT SENSORY AND MOTOR EXAMINATION

Swallowing is an array of synergistic interdependent movements, initiated by a complex set of sensory inputs that generate motor responses. These motor responses create pressures and forces for propelling ingested materials through the upper aerodigestive tract and simultaneously protect the upper airway. Though the VFSS does not employ direct measures of sensation and muscle strength, the following evidence suggests that trained examiners can make accurate and reliable clinical judgments regarding the presence of sensory and motor impairment. The following description of VFSS observations will be characterized as, *physiologic components*. The majority of the observed components contribute to judgments of both sensory and motor impairment because the initiation and integrity of the motor response is in part dependent on sensory input. A prime example of this combined sensori-motor

assessment is observation of the motor events that take place early in the pharyngeal swallow. If these events are delayed for several seconds, it is likely that the sensory input to the pharyngeal motor response is decreased below the normal level required to initiate the cascade of pharyngeal motor events. The clinician evaluates the sensori-motor relationships during the VFSS and administers various bolus consistencies, textures, and sometimes taste in order to asses their effect on swallowing function.

SWALLOWING PHYSIOLOGY - FOUNDATION FOR VFSS

Swallowing is a complex physiologic event comprised of simultaneous and sequential contractions of muscles of the oral-facial region, pharynx, larynx and esophagus. Descriptions of swallowing physiology were attempted well before the development of a sophisticated modality for viewing the rapid contractions and movements of the muscles and structures associated with swallowing. In 1813, Magendie was the first to separate swallowing into *phases* or stages representing the anatomic regions traversed by the “bolus,” or ball of material, to be swallowed [49]. The rapid sequential and overlapping motions characterizing adult human swallowing behavior were better appreciated with the introduction of radiography, and especially video radiography. Though phase descriptions remain in the current literature, the evidence suggests that the physiologic components of the process overlap and are interdependent as the bolus traverses the regional phases (oral, pharyngeal, esophageal) and has led clinicians to attempt assessment of the physiology of the swallowing, rather than reporting abnormality of a given phase. Further, the physiology will be the target of swallowing rehabilitation, and it is critical that these targets be identified prior to development of the treatment plan. Swallowing clinicians attempt to evaluate *components* of swallowing behavior on VFSS exams in patients presenting with clinical signs or symptoms of dysphagia (Table 1). From the observations of 15 literature-based components, clinicians also attempt to estimate the severity of the impairment(s) and make critical intake and diet texture recommendations, swallowing therapy recommendations, and predictions regarding the functional outcomes of the patient [38, 40, 41].

Whereas the late oral and early pharyngeal components of swallowing are the most critical from a safety point of view, the oral preparatory and early oral transport aspects of swallow are the most aesthetically and psychologically important. During the oral preparatory stage of swallow, the bolus is manipulated by lingual motion and masticated (if necessary). Though not a characteristic of natural drinking or eating behavior in most healthy individuals[50], the ability of a patient to contain a liquid bolus *(Component 1,* Figure 1a*)* in the oral cavity by an anterior lip seal and by lateral and posterior tongue to palatal contact (Figure 1b) is assessed. The proficiency of this task provides clinical information about the patient's ability to follow simple commands during swallowing – an important prognostic indicator for successful learning of compensatory swallowing strategies. Further, the ability to contain a bolus within the oral cavity provides information regarding oral motor control. The tongue is the major mobile element of the oral swallow and plays a complementary role in bolus preparation and mastication. The tongue also plays a major role in bolus containment and airway maintenance [51, 52]. The back of the tongue assumes a slightly elevated position due to contraction of various muscle groups, and opposes an actively contracted soft palate that is drawn downward and forward *(Component 2,* Figure 1b*)*. This glosso-palatine mechanism *(Component 3,* Figure 1b*)* ensures that portions of a liquid bolus do not fall prematurely over the base of the tongue (35, [43]). The ingested material is mixed with saliva and tasted during rotary mandibular chewing (*Component 4*), a motion that is integrated into the oral swallowing process and propelled through the oral cavity via lingual motility [51-54]*(Component 5,* Figure 1c, d*)*. When adult humans eat natural bite sizes of solid foods, portions of the food may be propelled to and accumulate in the pharynx during mastication.[54] If there are inefficiencies in the system, such

as muscle weakness or sensory loss, residual material may remain in the oral and/or pharyngeal cavity placing the patient at risk for inadequate nutrition/ hydration or airway compromise.

As the bolus is propelled through the oral cavity via upward and forward motion of the tongue, the head of the bolus reaches the region of the posterior oral cavity or oropharynx. When the sensory receptive fields in these areas are stimulated, the pharyngeal swallow is initiated *(Component 6*, Figure 1e*)* and the respiratory pause to accommodate swallowing is obligatory at this time [51, 52, 55]. Although the onset of the pharyngeal swallow is variable in its time of occurrence relative to the position of the bolus [56], when initiated the pharyngeal swallow is characterized by five mechanical events that have been shown to overlap during synchronized videorecordings of structural movements during swallow. These events function to protect the airway and clear the pharynx of ingested material and include: 1) elevation and retraction of the soft palate *(Component 7,*Figure 2a***); 2)** elevation and anterior displacement of the larynx *(Component 8,*Figure 2b) and hyoid bone (Figure 2c) ; 3) laryngeal closure *(Component 10,* Figure 2d*)*; 4) pharyngeal contraction *(Component 11)*; and 5) opening of the pharyngoesophageal region *(Component 12,*Figure 2e*)*[1, 28, 35, 36, 40, 41, 43-48]. Contraction of the pharyngeal constrictors (Figure 2f) is coincident with the forceful retraction of the tongue *(Component 13,*Figure 2g*)* that applies strong positive pressure on the bolus tail assisting in pharyngeal clearance and prevention of pharyngeal residue [5, 44, 47]. The hyoid bone and larynx move as a functional unit in a superior and anterior trajectory during a normal, nutritive swallow. These critical motions, observed during the VFSS, are physiologically linked to effect vestibular closure (i.e., via approximation of the arytenoid cartilages and the epiglottic petiole together with full inversion of the epiglottic tip) (*Component 14*) (Figure 2f, 2h) and to opening and distension of the pharyngoesophageal segment (PES) (Figure 2e). Opening of the segment permits entry of the ingested material into the cervical esophageal region [5, 44, 45, 47, 48, 57]. The traction placed on the cricoid cartilage during this brisk motion pulls the cartilage anteriorly and away from the posterior pharyngeal wall, opening the compliant PES region (Figure 2e) [5, 44, 45, 47, 48, 57]. This compliance is related to early relaxation of the cricopharyngeal muscle, the primary muscular component of the segment[55]. As the larynx descends toward its rest position in the latter stages of pharyngeal swallowing, respiration is resumed and characterized by a small expiratory airflow in most adult human swallows [58-60].

The mechanics of the esophageal body and lower esophageal sphincter are less complex and easier to study because of their slow speed relative to oropharyngeal swallow events. The bolus head enters the cervical esophageal region through the distended PES, continues through the esophagus and is propelled and cleared *(Component 15,* Figure 3*)* via primary and secondary esophageal peristaltic muscle contractions [61, 62]. These contractions continue until the bolus head and tail progress through the passively relaxed lower esophageal sphincter (LES) and advance into the stomach. There are a few behavioral interventions available to modify the contractile characteristics of the esophagus and improve esophageal clearance [41]. However, clinical evidence and preliminary research indicate that *esophageal clearance in the upright position* appears to have some functional impact on pharyngeal clearance and possible airway protection [63]. Therefore, observations of esophageal clearance in the upright, eating and drinking position are made by clinicians during the MBS exam in order to gain an impression of the potential impact of incomplete or slowed esophageal clearance on oropharyngeal swallowing function, on the potential for aspiration of residual esophageal contents, and on the nutritional status of the patient.

The anterior-posterior image projection is the optimal view for assessing the efficiency of esophageal clearance in the upright position. Further, this viewing plane is best suited to determine the overall symmetry of oropharyngeal swallowing function and to determine the immediate effectiveness of compensatory postures.

MOVE TOWARD STANDARDIZATION

By definition, a gold standard is a test by which all other tests are measured and the VFSS has often been described as the gold standard for the evaluation of oropharyngeal swallowing. However, it is unlikely that a single test will be the “best” test for the assessment of swallowing for every patient and every patient condition. Other imaging methods such as flexible endoscopy may supplant or complement the VFSS examination. Nonetheless, clinical utilization data indicate that VFSS is the method of choice by most practicing clinicians and efforts should be taken to standardize the examination protocol, terminology used to describe swallowing behavior, and the method for quantification of swallowing impairment. The current state of affairs is that clinicians have not adopted a universally accepted terminology or a tool that has been empirically based, reliable, and valid for converting clinical information into a quantifiable metric for the diagnosis of swallowing impairment. Empirical evidence and standardization have been lacking for the selection of the measured physiologic components, the types of measures that are employed, and categorization of functional swallowing components into regional domains (i.e. phases). This lack of standardization in measurement methods across clinics and laboratories impedes our understanding of true functional results in studies that profess to document rehabilitative (swallowing therapy) and restorative (surgery and medications) effects of treatment, produces ambiguous reporting of outcomes, and hinders our understanding of what restorative and rehabilitative targets should be in order to impact the overall health and well-being of dysphagic patients.

The Agency for Health Care Research and Quality (AHRQ) reports[64]:

- Standardization is critical to supporting valid comparisons and benchmarking across health care settings
- Comparability is what makes the information useful for quality improvement as well as public reporting
- Assures users of the results that the validity and reliability built into the instrument by the developers is maintained
- Adaptation of a voluntary standards system will lead to optimization of patient care quality, safety, efficacy, and cost

AHRQ further reports that voluntary standards should be applied to the content and format of the test instrument, to the data collection protocol, the analyses and interpretation, and reporting. Translating Research into Practice-II initiative focused on the implementation of techniques that factors associated with successfully translating research findings into diverse applied setting. This initiative bought clinician accountability to the forefront in clinical practice. The report stated that the increased demands for accountability in health care, including reporting of clinical performance using standardized quality measures, have created a sense of urgency regarding needed improvement in these areas within health care organizations and clinical practices.

STANDARDIZATION: VFSS PROCEDURE AND PROTOCOL

The descriptions if the VFSS as originally described by Logemann continue to be followed in the majority of clinical practices [40, 42, 65]. Patients are initially positioned in the lateral view, and regions of visualization include the oral cavity, pharyngeal cavity, larynx, and cervical esophagus. The visualization field includes the lips anteriorly, nasal cavity superiorly, cervical spinal column posteriorly, and the entire pharyngoesophageal segment (PES) inferiorly [35, 38, 40, 41, 43]. The larynx should be in full view within this visualization field. The VFSS takes place in a standard radiology fluoroscopy suite. The fluoroscope is activated by the radiologist for a few seconds prior to and then following the administration of the barium substances. The

fluoroscope is deactivated shortly after the bolus tail had exited the cervical esophageal region. The lateral view is ideal for judging movements that generate pressures, open and closure critical valves during the swallow. The patient is then positioned in the anterior-posterior (i.e. frontal) viewing plane so that judgments may be made regarding symmetry of bolus flow, pharyngeal wall contraction, and symmetry of structure and function when viewing bolus flow. All patients should ideally be examined in both the lateral and frontal positions. An examination performed in the lateral position only can miss vital abnormalities that can be appreciated only in the frontal position. For example, examination in the frontal position is essential to detect unilateral abnormalities such as unilateral pharyngeal paresis or paralysis and unilateral vocal fold paralysis. The total radiation exposure averaged 3–5 minutes, an amount typically encountered in an upper gastrointestinal series. The examination may be extended depending on the nature and severity of the patient's swallowing problem and condition, however, the goal of minimizing radiation exposure while maximizing clinical yield is consistently maintained.

Accurate analysis requires video freeze-frame and slow motion capability. Dynamic recording at a minimum of 30 video frames/second is essential for detecting the rapid movements and bolus flow events associated with oropharyngeal swallowing and is easily accomplished by linking a recording device to the fluoroscopic unit. A 100- or 105-mm spot-film camera with maximum frame rates of 6–8 frames/sec is inadequate for evaluation of swallowing (e.g., subtle but critical laryngeal penetration or aspiration may be visible on only one or two frames of a 30/second sequence)[42, 65].

The VFSS typically includes the administration of various bolus volumes and textures because data has demonstrated the potential physiologic benefits of manipulating these sensory variables. However, the consistencies of the contrast material and the volumes administered have not been standardized across most clinics. One reason for this state of affairs is that clinicians often introduce certain consistencies based on their clinical intuitions of the likely patient performance. However, there has been no validation for implementation of such practices.

A recent study [66] has demonstrated the need and feasibility of standardizing contrast materials. The Martin et al study [66] determined the contribution of bolus volumes, consistencies, and textures to the overall impressions of swallowing component scores. While the investigators identified a role for most commonly tested, standardized volumes of thin liquid, nectar thick liquid, honey thick liquid, pudding, and cookie to one or several of the component impairment scores, 5 ml of thin and nectar thick liquid provided sufficient information that allowed trained clinicians to make reliable assessments of the 15 physiologic swallowing components. If 5-ml liquid (thin and nectar) continues to demonstrate contribution to judgments of impairment in subsequent studies, these two swallow trials may serve as “screening swallows” that signal the need to progress or perhaps, conclude the MBS exam. This finding certainly speaks to the potentially misguided practice of foregoing the thin liquid swallow with the perception that the patient will perform better (i.e., less aspiration) on a more viscous bolus.

STANDARDIZATION: VFSS TERMINOLOGY, INTERPRETATION, AND REPORTING

In addition to testing the role for standardizing the VFSS protocol, the study described above also set out to rigorously test the reliability, content, construct, and external validity of a new modified barium swallowing (MBS) tool (MBSImp) used for quantification of swallowing impairment [66]. The tool includes an ordinal scaling methodology of each of the previously described set of physiologic components whereby each score represents a unique observation from the VFSS. The tool demonstrated content and construct validity as well as good

concordance between and within clinician scoring. Further, because the VFSS represents a clinical simulation of a feeding/eating experience, any measures of impairment gained from the test should demonstrate relevance to the functional outcome of the patient. The tool was examined for this relationship and the measures of swallowing impairment demonstrated good external validation via statistically significant correlations with blinded outcome assessments of diet, health status, nutrition, and quality of life.

Adaptation of such a voluntary standards system will lead to optimization of patient care quality, safety, efficacy, and cost. Standardized practices facilitate inter-institutional exchange of patient data using electronic data collection, aggregation, and reporting systems [64, 67]. The results of this study demonstrate the achievement of a critical strategic step toward achievement of standardization of swallowing assessment. Implementation of such standardized training, protocol, contrast materials, and measurements should improve our ability to compare the swallowing impairment exhibited by our dysphagic patients during the course of recovery or physiologic decline associated with natural histories of progressive neurological diseases across clinics and clinical lab.

VFSS - A REHABILITATION EXAMINATION

A primary purpose of a VFSS is to determine the effect of various behavioral and sensory interventions on the physiologic function of the swallowing mechanism. Several studies have shown the ability to detect immediate effects of compensatory strategies (bolus volume, consistency and taste, postural alterations, swallowing and respiratory maneuvers) on swallowing physiology [9, 14, 68-82]. The systematic application of these evidenced-based strategies, if applied directly to the observed physiologic impairment, often leads to the development of eating and drinking strategies that may be immediately implemented by the patient, care giver, and clinician. Swallowing rehabilitation strategies are described elsewhere in this edition and will not be repeated here. Though patients may not be deemed safe for immediate oral intake following the exam, the importance of the VFSS for optimizing oral intake within the limits of the patient's physiologic potential can not be understated. We have learned that proper administration and interpretation of the examination has the potential to upgrade oral intake status and diet textures as well as to make recommendations for oral intake restrictions[38, 83]. Recommendations are not only based on the patient's physiologic status, but also on their cognitive status, care giver situation, and the nature of the underlying disease or condition.

SUMMARY

The VFSS has been shown with strong evidence to be the ideally suited method for the identification and quantification of the presence and nature of oropharyngeal and cervical esophageal swallowing disorders. The ability to assess overlapping and interdependent structural movements as they relate to bolus flow in real time throughout the swallowing process has demonstrated high clinical yield. When the VFSS protocol is standardized, interpreted, and reported by trained clinicians using standardized and validated measures, treatment can be systematically applied during and after the examination according to the physiologic swallowing problem. Further, change in the patient's swallowing performance and responsiveness to swallowing interventions can be consistently applied and communicated across clinics and hospitals. These standardized practices will result in seamless patient care and optimize the patient's swallowing treatment throughout the continuum of care.

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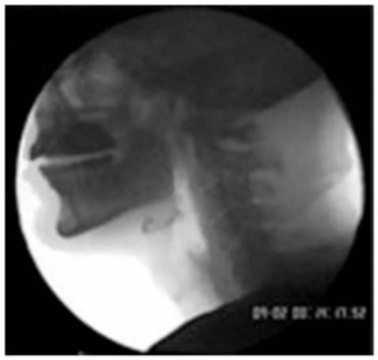
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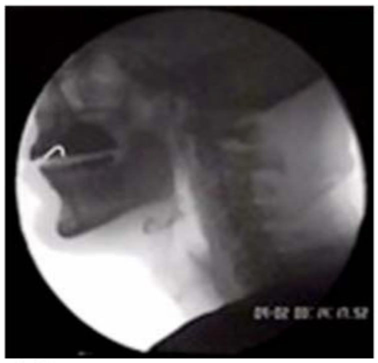
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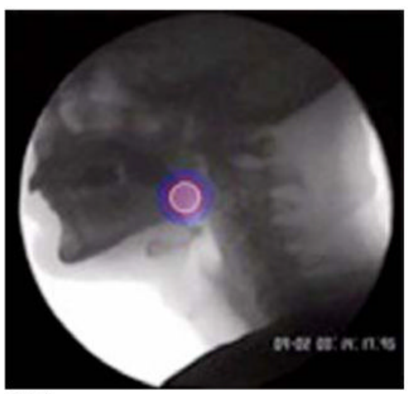
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1. Oral Components of Swallowing as depicted on lateral views from VFSS recordings

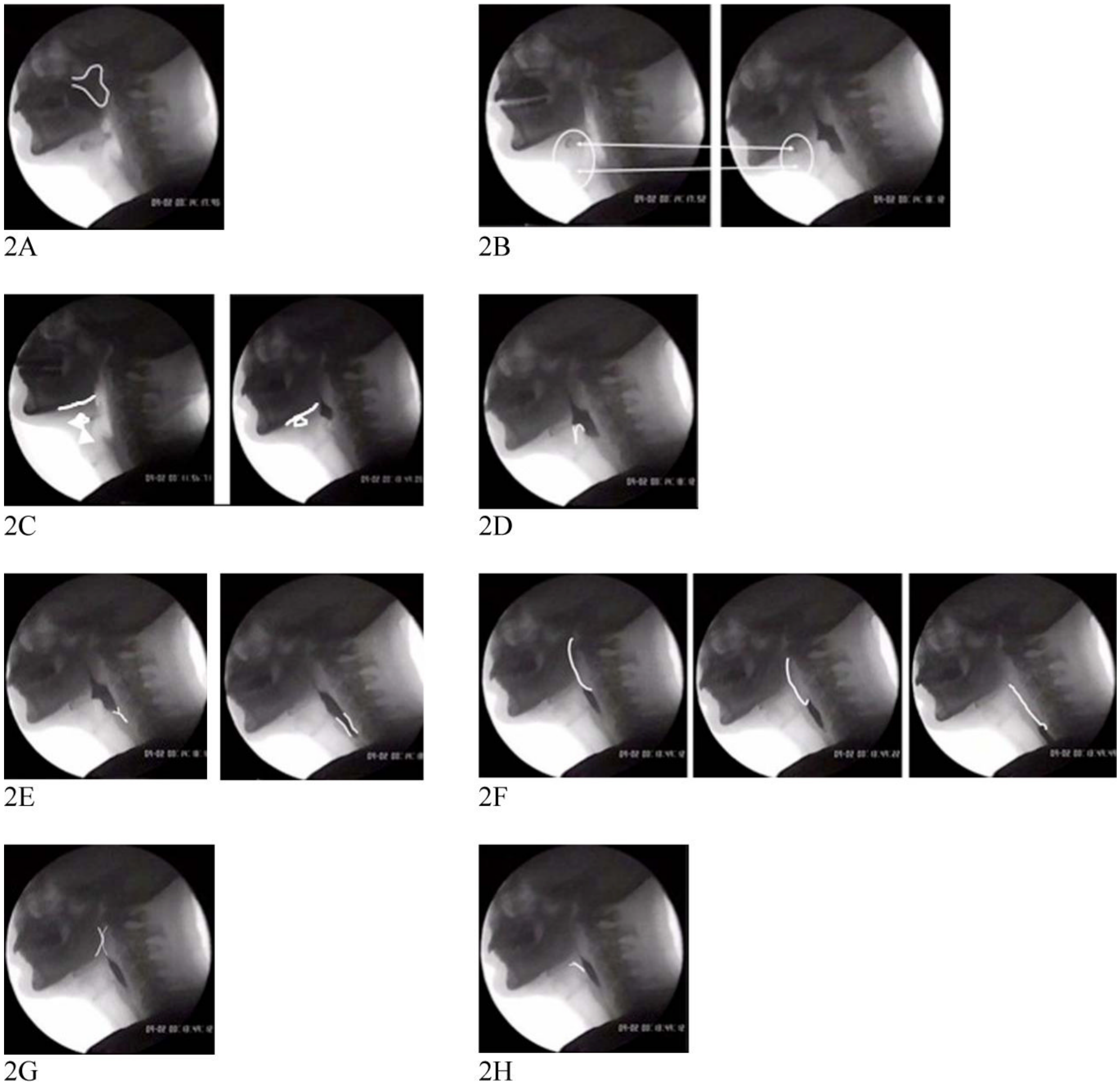
Figure 1A oral containment via anterior lip seal

Figure 1B tongue to palatal contact

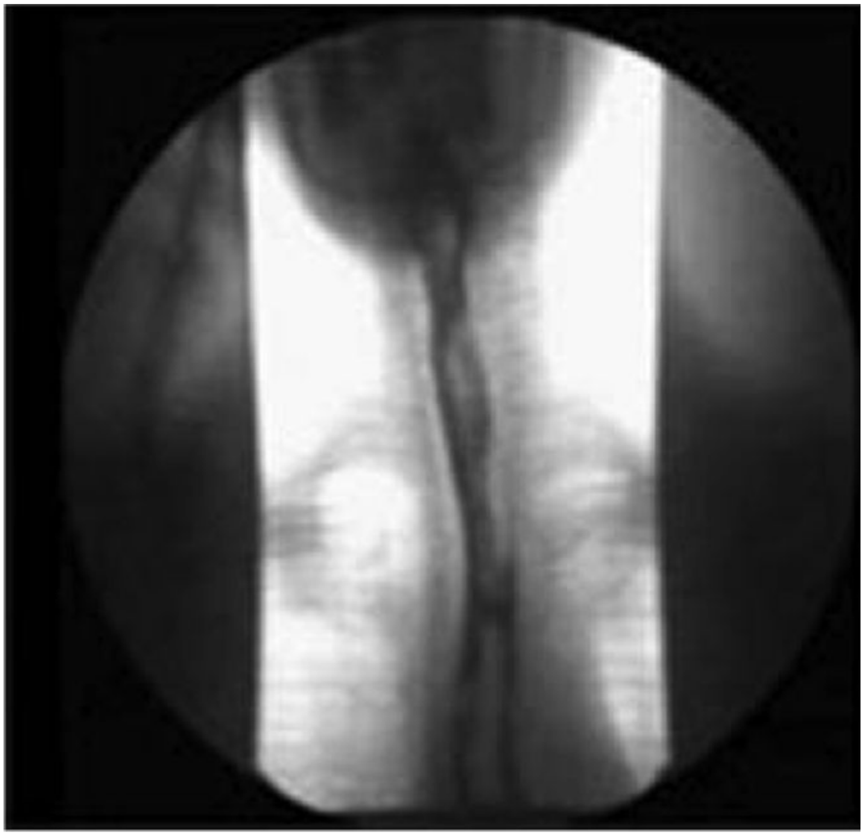
Figure 1C early

Figure 1D mid-lingual motility during oral bolus transport

Figure 1E initiation of the pharyngeal swallow



2. Pharyngeal Components of Swallowing as depicted on lateral views from VFSS recordings
Figure 2A elevation and retraction of the soft palate
Figure 2B elevation and anterior displacement of the larynx
Figure 2C hyoid bone
Figure 2D laryngeal closure via apposition of arytenoid cartilages to epiglottic base Figure 2E opening and distension of pharyngoesophageal segment
Figure 2Fpharyngeal contraction and stripping wave
Figure 2G tongue base retraction and apposition with posterior pharyngeal wall
Figure 2H epiglottic inversion



3.

Esophageal Clearance in the upright position as depicted in the anterior-posterior view from VFSS recording

Table 1

List of 15 physiologic components assessed during the VFSS.

1.	Lip Closure
2.	Lingual Elevation
3.	Tongue to Palatal Seal
4.	Bolus Preparation/Mastication
5.	Bolus Transport/Lingual Motion
6.	Initiation of Pharyngeal Swallow
7.	Soft Palate Elevation and Retraction
8.	Laryngeal Elevation
9.	Anterior Hyoid Excursion
10.	Laryngeal Closure
11.	Pharyngeal Contraction
12.	Pharyngoesophageal Segment Opening
13.	Tongue Base Retraction
14.	Epiglottic Inversion
15.	Esophageal Clearance