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REVIEW

History of Fiberoptic Endoscopic Evaluation of Swallowing for Evaluation and Management of Pharyngeal Dysphagia: Changes over the Years

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A Personal Note

Back in 1988, when the first description of the FEES procedure was published [1], otolaryngologists had just started to use fiberoptic laryngoscopes in their practice. Prior to fiberoptic technology, laryngoscopy was performed with a mirror or more invasive direct laryngoscopy instruments. The first fiberoptic laryngoscope is generally credited to Sawashima and Hirose in 1968. It transformed the practice of laryngoscopy by allowing a transnasal approach with the patient conscious during the procedure and providing a view of the vocal folds during natural speech.

Commercial fiberoptic laryngoscopes were not commonly available until the 1980s. I was practicing in Ann Arbor Michigan at the time. In our ENT clinic, the rigid mirror exam was the first exam administered—and if indicated, a transoral laryngoscope was used. Over a relatively short period of time, however, the fiberoptic laryngoscope became the exam of choice for viewing anatomy, physiology, and for biopsies of suspicious masses.

The Speech Pathology and Otolaryngology clinics at the Ann Arbor VA shared space and I often watched an ENT exam done on a voice or head/neck cancer patient. It occurred to me that the anatomical region we were most interested in for swallowing function and for detecting aspiration—the larynx- was beautifully portrayed. So, Dr. Nels Olson (ENT faculty), Ken Schatz (SLP), and I explored the ability of the laryngoscope to evaluate swallowing. We hoped that this procedure would enable us to assess a patient at bedside when the patient was unable to get to the Radiology suite. We were disappointed at the lack of information from a healthy volunteer, but when we began to assess patients with dysphagia, we were thrilled. We could visualize spillage, aspiration, residue, structural movements and secretions. We were onto something.

Technological Advances in FEES

The FEES procedure as it is done today bears little resemblance to the early exams done in the mid 1980s. The examiner looked through the eyepiece and tried to identify and remember everything he/she saw. Of course, only the examiner looking through the eyepiece saw anything, and much was missed because swallowing is a dynamic event. As our technology advanced, so did the usefulness of the procedure. Cameras, monitors, and video recorders have all taken exponential leaps to give us the sophisticated systems we have today. The laryngoscopes are far superior to the early versions. High-resolution technology has made the view of the surface anatomy incredibly sharper. Durable, small LED light sources have replaced xenon and halogen lights. Digital recording has made it possible to use a laptop as the videorecorder. Many of the manufacturers have low end systems that are affordable for more users. Figure 1 gives a glimpse of the improved picture rendered by the high-resolution system.

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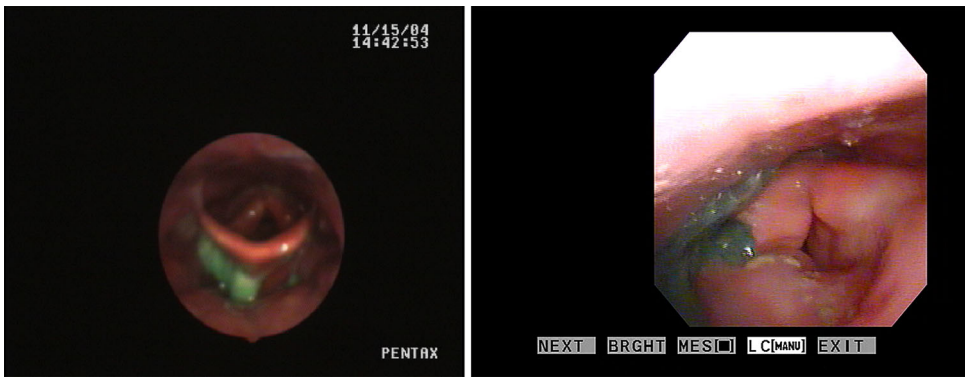

Fig. 1 Comparison of endoscopic view taken from an old fiberoptic scope and a new distal chip scope. Residue seen from fiberoptic scope. Residue seen from distal chip scope

Growth of FEES

FEES or Fiberoptic Endoscopic Evaluation of Swallowing, as it was named, has evolved from a procedure done by a handful of curious people to an established procedure that stands alone. A comprehensive textbook covering all aspects of this procedure was published in 2001 [2]. The acceptance of FEES was tenuous at first, with many skeptics dismissing it as a fringe procedure. Today, the situation has changed dramatically. In some parts of the world, FEES is the primary procedure done on patients with suspected pharyngeal dysphagia, with other procedures following only when the diagnosis is incomplete. This procedure is often compared to the videofluoroscopic swallow procedure (VFSS), also known as the Modified Barium Swallow (MBS). Because VFSS was already an established procedure when FEES was first described, VFSS is often referred to as the 'gold standard.' However, others would argue that being there first does not make you better.

Comparison to Videofluoroscopy

There have been dozens of publications comparing the two exams. Most of these designs have entailed giving a patient both exams and comparing the findings. They were consecutive exams, sometimes close in time, and sometimes as far as a week apart. The boluses given were usually not identical in consistency or size. It is surprising, then, that the two exams agreed so closely in regard to the 'bolus findings' of spillage, residue, penetration, and aspiration [3–10].

Four publications should be given more weight. These studies were done using simultaneous fluoroscopy and endoscopy equipment while the patient swallowed various foods or liquids. Thus, the same bolus was compared, and the same swallow was compared. Multiple raters were used to judge either presence/absence of the bolus findings [11] or they were asked to rate severity of residue [12, 13] or to score penetration/aspiration on the PAS (Penetration/Aspiration) Scale [14]. One study asked the raters to mark the different locations where residue was seen within the hypopharynx or larynx [13]. In summary, these studies found that agreement for presence/absence of findings was very high but that FEES consistently yielded a worse score in terms of increasing severity of the finding of interest. PAS scores were higher/worse when the swallow was rated from FEES. Residue was judged to be more severe, and residue was seen in more locations. Figure 2 shows an example of two views of the same frame where spillage has occurred and the patient is about to swallow some liquid.

The results of these 'simultaneous' studies argue against the MBS study being the gold standard. The gold standard should represent the truth as close as we can ascertain. FEES is more sensitive to bolus findings, and in the case of detecting the presence of a bolus, it is clearly superior.

However, if the goal is to rate the problem on a categorical scale (mild, moderate, severe), it becomes more difficult to decide whether FEES or fluoroscopy represents the "truth." This issue will be taken up again in the section, below, titled Scoring a FEES Exam: Scoring Residue.

Safety of FEES

A legitimate concern about FEES regards safety. Although flexible laryngoscopy is done by otolaryngologists daily as a routine examination and is thought to be a benign procedure, the question about safety of FEES is still relevant since many non-physicians perform FEES and therefore are not equipped to be a 'first responder' should anything happen. The most commonly reported adverse effects are (1) epistaxis, (2) vasovagal response, and (3) laryngospasm. One could argue that an added risk of FEES is aspiration of the food/liquid given to them. However, this is often disregarded since it is a risk faced by the person whether or not the event of aspiration is witnessed directly.

There have been a few reports of the safety record of FEES. In 2000, Aviv and colleagues collected data on 212

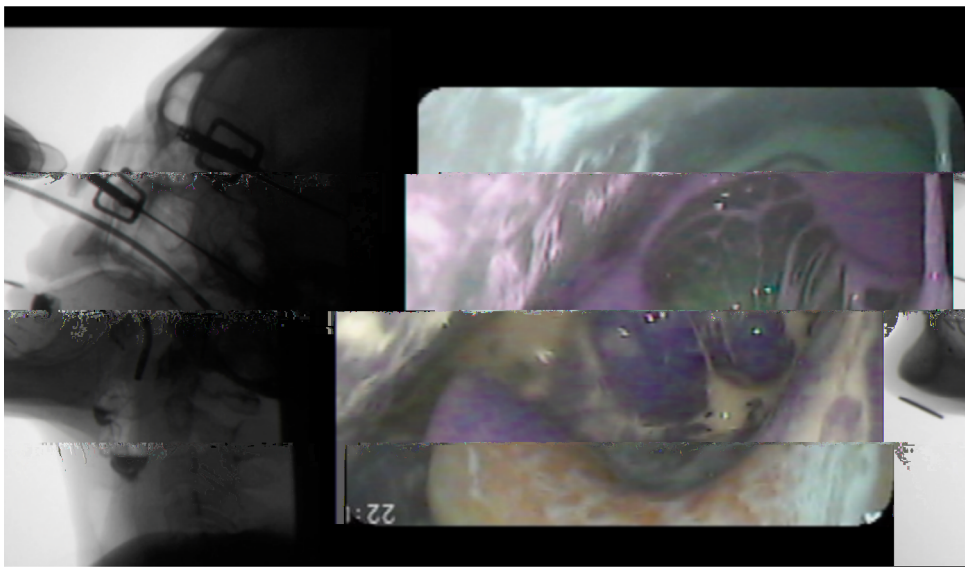

Fig. 2 Simultaneous view of bolus spillage prior to swallow

inpatients and outpatients given FEES exams over a 2.5-year period [15]. The most common diagnoses of the study patients were stroke and other neurologic diseases. Results showed no instances of airway compromise or laryngospasm, 6 cases of epistaxis (1.2%), all self-limiting, and no significant change in vital signs before and after the procedure. These authors reported on another series of 1340 patients in 2005 [16]). Incidence of complications were fewer than in their initial study (epistaxix = 0.07%) and no instances of airway compromise. Willging reported safety data for over 500 pediatric FEES exams [4]. There were four cases of epistaxis and no cases of laryngospasm. More recently, in 2016, a report of complications in 2820 FEES exams was published [17] Subjects included inpatients and outpatients. They reported 4 cases of epistaxis (0.14%), three cases of vasovagal syncope (0.1%), and 2 cases of laryngospasm (0.07%), three of which occurred in patients with ALS. All resolved spontaneously. In summary, FEES has been shown to be extremely safe with all reported complications being minor and spontaneously resolved.

A patient population that one might consider at high risk for epistaxis is the acute stroke patient. In a series of 300 acute, severe stroke patients who were given a FEES within 2 days of the stroke, there were no reported instances of epistaxis, change in level of consciousness, laryngospasm, or bradycardia/tachycardia that required special treatment. This was in spite of the fact that many patients were on anti-coagulant therapy or antiplatelet drugs [18]. Thus, FEES appears to be safe, even for acute stroke patients.

Another safety-related concern that is often raised regarding FEES is the use of topical anesthesia. For many years, there existed conflicting results of studies that found the use of a topical anesthesia either did or did not compromise the swallow. [19–21]. Most clinicians agree that some people feel the exam to be more comfortable with anesthesia to the nares, but if it compromises the swallow, it should not be used. In a series of three studies, researchers at Boston Medical Center and Wake Forest Medical Center collaborated to determine what level of anesthesia, if any, could be used to make patients more comfortable without affecting the swallow. In the first study, Lester [22] found that healthy adults did have a significant change in their Penetration/Aspiration Scale (PAS) scores when they were given 1 ml of 4% lidocaine before the exam ($p = 0.002$). Fife followed this study by giving 0.5 ml of lidocaine to patients with dysphagia and found that PAS scores were not significantly changed ($p = 0.065$) [23]. However, they were uncomfortable with the close results and so this was followed by a third and final study done by O'Dea [24] where the dose of lidocaine was reduced to 0.2 ml. Thin liquid and puree boluses were given. Results showed no significant difference in the anesthetized vs. non-anesthetized conditions for PAS or residue scores. Of note, the patients did rate the exams done with lidocaine significantly more comfortable, especially on insertion of the scope ($p = 0.04$).

FEES Protocols

FEES is *not* a screening exam to merely identify aspiration. The FEES examination developed by Langmore is comprehensive. It has not undergone validity testing so it remains a guideline [2]. It describes three parts to the exam: In Part 1, anatomy is observed, secretions are rated, and movement of structures in view (velopharynx, base of tongue, pharyngeal walls, and larynx) are rated by asking the patient to perform non-swallow, speaking and breath-

holding tasks. Formal assessment of sensation is also included. In Part 2, the direct evaluation of swallowing occurs as the patient eats and drinks various bolus consistencies. These can be measured and delivered to the patient in a structured order or can be self-administered in a non-structured task (e.g., "eat everything here as you wish"). Part 3 is described as the Intervention portion of the exam, where postural, dietary, and behavioral changes are trialed as problems occur.

While some examinations need to be administered completely and with items in a consistent order, this is not always preferable. Several publications have described FEES protocols and scoring systems that are customized for particular patient populations. Warnecke and Dziewas have developed and validated protocols for Myesthenia Gravis [25], Parkinsons disease [26], Progressive Supranuclear Palsy [27], and stroke [28–30]. Farneti has developed a method to assess the oral stage of swallowing using a laryngoscope with a wide angle deflection (personal communication). Baijens explored the predictability of aspiration in a study where patients were given multiple liquid swallows, until aspiration appeared [31]. They found that over time, the likelihood of aspiration increased (e.g., after 3 trials of thin, 46% of the patient aspirated but after 10 trials, 68% had aspirated). This last study emphased the need to give multiple trials in order to gain a realistic impression of the patient's real-life swallowing function.

Three Part 1 tasks (non-swallow, phonatory tasks) described by Langmore have been supported by subsequent research. In a simultaneous endoscopy and fluoroscopy study, Fuller [32] validated the pharyngeal squeeze task (non-swallow, phonatory FEES task), by comparing it to patients' PCR (pharyngeal constriction ratio) as measured by fluoroscopy during the swallow. Murray [33] developed a secretion rating scale to be included in the Part 1 section of FEES that had significant ($p = 0.001$) predictive value for aspiration. Later studies supported this scale with good reliability [34]. A similar scale for rating secretions has also been validated [35]. Finally, preliminary validation was found for the Part 1 "Glide up" task, by comparing muscles engaged in this task to that of muscles used in lifting the larynx during swallowing [36]). Other Part 1 tasks remain to be validated.

Sensory testing is an optional Part 1 task. Formal sensory testing was popularized by J Aviv [15, 16, 37–39] in what was called FEESST (FEES + Sensory Testing). It entailed delivering an air pulse with a calibrated amount of pressure to the mucosa at the juncture where the arytenoids meet the AE folds. The examiner then looks for the laryngeal adductor reflex (LAR) which will occur if the air pressure was at threshold level or higher. Aviv reported a significant association of sensory deficits with aspiration of food or liquid, especially when found in combination with an impaired pharyngeal squeeze [38]. Since their initial publication there have been numerous publications that applied air pulse sensory testing to children [40–42], to patients with head/neck cancer [37]; reflux [43, 44]; and to other neurologic diseases [45]).

Unfortunately, this equipment is no longer commercially available. The 'touch' test has replaced the air pulse test in most clinics, where the examiner lightly touches the arytenoid and looks for the laryngeal adductor reflex as a response. Kaneoka [46] compared the sensitivity of the two methods for their association with penetration and aspiration. Not surprising, the air pulse method identified sensory impairments more frequently ($p < 0.00001$), but importantly, only the touch method was significantly associated with abnormal PAS (penetration/aspiration) scores ($p = .05$). Thus, the touch method may, in fact, have more clinical relevance. This needs further exploration.

In Part 2 of the FEES examination, patients are given food and liquid to eat/drink and swallowing is evaluated directly. While food can generally be seen easily if it appears in the hypopharynx, clear liquid may pass by quickly and leave no trace of its pathway. This makes it more difficult to judge whether aspiration occurred, particularly if it occurred during white-out. Thus, Langmore and others suggest putting a few drops of green food coloring into a clear liquid to help with visibility. However, a liquid that leaves a coating behind on the mucosal surfaces (for example, milk) is superior to a clear liquid for visibility. Some wonder if the green dye is necessary if milk is used instead of a clear liquid. Leder [47] concluded that white (milk) was detected as easily as milk that was dyed green. Following this, however, a careful design by Marvin [48] found that a few drops of green food dye added to the milk significantly improved detection of penetration and aspiration ($p \leq 0.05$), particularly when the patient had excess secretions that could be confused with white liquids, especially if coughed up.

Some patients refuse or are allergic to milk. A newer product that has proven very successful in leaving a coating similar to milk is white food dye, used by bakeries for icing cakes. Various makers of this product can be found on the web.

Ice Chip Protocol

One advantage of a FEES examination is that very severe patients can benefit from the exam. A finding of excess secretions in the larynx is highly predictive of a severe dysphagia and/or aspiration [33, 49]. Some patients who have been nil per oral decrease their frequency of spontaneous swallows over time, especially if they are tracheotomized and fed via a feeding tube. However, clinicians should not refuse to treat these patients and

'wait' until they swallow better. The Ice Chip protocol was developed for patients such as this. As described in the textbook by Langmore [2], it simply entails assessing anatomy and physiology as much as possible (Part 1), and then, if the patient has difficulty swallowing spontaneously, the examiner gives him an ice chip or two (about 2 ml), asks him to move the ice chips around in his mouth, and then 'swallow them all at once.' This bolus will stimulate swallowing, yet is a very safe bolus if aspirated. Sometimes, a patient needs three or four ice chips before the swallow mechanism 'wakes up' and the swallow is triggered more easily. After each swallow, the status of secretions is assessed. If the swallows helped to reduce the secretions, it is a good prognostic sign. Recommendations vary, of course, but they are often to give the patient ice chips for the next few days to wake up the system and help strengthen the swallow. Then, a FEES re-evaluation is warranted.

Scoring a FEES Examination

In her textbook, Langmore included a detailed score sheet for abnormal swallow findings [2]. Hey and colleagues reported on two studies that examined the scoring system advocated by Langmore. In the first report [50, 51], they found that total time to write a report decreased by about 1/3 and comprehensiveness of the exam increased by about 1/3 when a formal documentation system was used to guide the report writing. In a second study, these researchers [52] found that scoring of penetration and aspiration improved when the study was recorded and could be reviewed as needed ($p = 0.004$).

The FEES scoring system developed by Langmore was not validated at the time of publication. Since that date, other investigators have used their versions of FEES scoring systems to examine reliability and validity of the exam results. Pilz [53] found good inter- and intra-rater reliability for 4/4 key events, with the exception of post swallow pooling of thin liquids. Using a standard FEES protocol, Baijens and colleagues found significant associations between 2 of the 4 different FEES scoring parameters and quality of life (anxiety and depression) in a mixed group of outpatients [54]. In another study [55], this same group found a significant association between the results of the FEES parameters and swallowing-related QOL in head neck cancer patients as measured by the MDADI (MD Anderson Dysphagia Inventory) [56]. Finally, they have applied sophisticated modeling to identify different patterns of dysphagia [57].

Two particular parameters scored on a FEES examination have received the most attention: aspiration and bolus clearance or residue.

Scoring Penetration and Aspiration

Many published studies using FEES as the diagnostic tool have used the Penetration–Aspiration Scale (PAS) [58] to describe dysphagia or to study outcomes of treatment. Two studies of particular interest looked specifically at the Penetration/Aspiration Scale (PAS) [58] to study reliability and sensitivity. Using 79 swallows and 4 judges, Colodny [59] reported that inter-rater reliability was equally good when visualized endoscopically as had been reported for fluoroscopy studies. A subsequent study by Butler [60] reported excellent inter-rater reliability among clinicians assigning a PAS score to 35 swallows. This held up whether the clinicians were new or experienced in FEES. Kelly [14] compared clinician ratings of PAS from recorded swallows visualized endoscopically and fluoroscopically taken from simultaneous studies. They found the PAS score was significantly different when scored from a FEES vs a fluoroscopy exam—and that the FEES scores tended to be worse. In other words, FEES was detecting more events of penetration than the MBS study—and more events of aspiration.

When reading these results, a reasonable question is: how can that be? There is a half second of white-out in the FEES exam when nothing can be seen. Would that not, by itself, lead to greater sensitivity for fluoroscopy? The authors did not address that concern. It seems there are a few possible explanations. First, it has been reported from two large studies of patients with mixed diagnoses that more than 90% of all events of aspiration occur before or after the swallow (or white-out) [59, 61]. This is fortunate because FEES users have the view at those times. Second, it the patient expels material after the swallow, the expelled bolus is evidence of aspiration. Finally, evidence of aspiration can be seen if the bolus entered the airway from the anterior commissure because it will leave a coating of residue on the sub-glottic shelf. In fact, this small amount of material will likely not be visualized on fluoroscopy at all, as confirmed from viewing simultaneous studies [13].

It should be noted that aspiration is not a simple event and should not be scored only using the PAS. When interpreting an instrumental exam, it is imperative to determine when the event of aspiration occurred, as this will help to explain the reason for the aspiration and will determine the appropriate treatment. For example, it has been reported from FEES exams that head/neck cancer patients usually aspirate *after* the swallow due to residue that spills into the vestibule as the airway opens up. Thus, the major underlying problem leading to aspiration is the inability to clear the bolus through the pharynx, and this is the problem that needs to be remediated [62]. A similar finding has been reported from investigators using fluoroscopy [63].

Scoring Residue

Residue is a surrogate measure of reduced bolus clearance, which is a consequence of reduced pharyngeal constriction, base of tongue retraction, and/or laryngeal excursion. If these structures cannot move within their full range, the bolus will not be completely cleared through the hypopharynx into the esophagus. If residue is seen, the examiner has two challenges: first, to determine which of these structural movements is reduced; second, to rate the severity of the problem. Several studies have reported that identifying the location of the residue is a strong indication of reduced pressure at that level [7, 64–67]. For example, residue seen on the base of tongue is an indication of reduced base of tongue pressure against the pharyngeal walls. This association was confirmed by doing simultaneous manometry and endoscopy or fluoroscopy studies. Thus, viewing the location of residue is meaningful for diagnosis and leads directly to treatment.

Rating the severity of the residue problem is more complicated, since this is a perceptual task. There are a multitude of residue scales that have been published. Most of these have been developed for fluoroscopy, but a handful have been developed for FEES exams [12, 53, 68–73]. The studies referenced here used a categorical scale (mild, moderate, etc.), other than Park who used a binary scale (less than 15% vs more than 15%). Some of these scales are to be applied at certain times (e.g., after the first swallow), while others can be applied at any time the examiner wants [73]. Some of the scales include aspects of residue that go beyond amount of residue seen and give credit for clearing swallows or take location of the residue into account for the final score [70, 72]. Two scales have been developed specifically for rating residue of secretions [33, 35].

Some of these scales have undergone validity and reliability testing and have fared well. However, several questions remain: What type of scale is best for rating residue? Pisegna compared categorical scales and visual analog scales (VAS) [74] and found high reliability for ratings overall for each, but some advantages for using a VAS. Secondly, can researchers develop a Residue scale that will yield the same score whether the swallow is seen fluoroscopically or endoscopically? As discussed above, Kelly [12] and Pisegna [13] found a discrepancy in clinician ratings of residue seen endoscopically vs. fluoroscopically. If interpretations of residue differ depending on the exam given, this may lead to different treatment or dietary recommendations.

Scoring Airway closure

Airway closure for swallowing involves sealing the larynx at 3 levels; vocal folds, arytenoid tilt forward to the base of the epiglottis, and epiglottal downfolding over the arytenoids. Many textbooks describe airway closure as an inferior to superior event, starting with the vocal folds, but two studies, using different physiologic signals, have contradicted that premise. VanDaele and colleagues [75] used simultaneous needle EMG and endoscopy to determine the order of muscle contraction and corresponding endoscopic view of the airway at the onset of the swallow. They found that in healthy adults, the most common order was: (1) arytenoid tilt forward to contact the petiole of the epiglottis and effectively cover the vocal folds and glottis, followed by (2) epiglottal downfolding over the arytenoids, and finally (3) vocal fold contact to seal the glottis. At last view endoscopically, before white-out, the vocal folds were still usually partly open. This same order of events was also reported by Ohmae [76] from simultaneous endoscopy and fluoroscopy studies.

This finding of airway closure has several important clinical implications. It is not uncommon to ask a patient to hold his breath before he swallows to impose early airway protection. In the VanDaele study, the subjects were asked to hold their breath and then swallow to see if the natural order of events would be altered. However, it was found that most subjects would break the vocal fold contact when they transitioned from breath-holding to swallowing, thus eliminating the early protection at the level of the vocal folds. However, if the instructions were altered and the subjects were asked to hold their breath very tightly and to keep their breath held tight during the swallow, this did alter the order of events—if the subject concentrated on tight airway closure, then the vocal folds, via sustained thyroarytenoid and interarytenoid contraction, maintained glottic closure throughout the swallow. This suggests that if the patient can learn this technique (in essence, the supersupraglottic swallow), airway closure will be maximized.

Scoring Timing of Swallow Onset

Structural movements can be reduced in amplitude or they can be mistimed with bolus flow. The most common problem in many neurologic etiologies is mistimed or delayed onset of the swallow. This is commonly reported as spillage time or pharyngeal delay time—calculated as the number of seconds from when the bolus enters the oropharynx until the swallow begins. Another measure often noted is the location of the bolus head when the swallow begins. Norms for this event have been established over the years by numerous investigators using fluoroscopy data [77–81]. Recently, Nagy [82] confirmed earlier findings that cued and non-cued swallows have different patterns—the cued swallows having shorter pharyngeal delay times. In a novel endoscopic study, using FEES as the tool, Dua studied natural eating/drinking in young healthy

subjects as they ate an entire meal [83]. This group of investigators found that spillage was even more pronounced in this situation than in cued or non-cued swallowing of single boluses. In fact, for 60% of liquid swallows and 76% of solid food swallows, the bolus entered the pharynx prior to initiation of the swallow. Because of these studies, the boundary between normal and abnormal spillage has become blurred, but it is clear that the environment (or structure) in which someone eats clearly affects timing. FEES may have the advantage in that real liquids and foods are trialed and various conditions can be tested with no time constraints due to radiation exposure.

Managing Dysphagia with FEES

During the initial FEES exam, compensatory strategies are usually trialed if any swallow problems are seen. These may be in the form of postural changes or modifications to the way a patient eats, or is fed. Compensatory strategies are part of nearly every patient's recommendations and the mainstay of patients who are demented or otherwise incapable of learning rehabilitation strategies such as exercises. The advantages of FEES over MBS is that real foods and liquids are used, there is no restriction in patient or clinician time, and the patient and significant others can be present and interactive during the exam.

In the case of acute care inpatients or ICU patients, compensatory treatment may consist solely of dietary recommendations that can be derived from the FEES procedure. Length of stay is a major cost factor in the inpatient setting and accordingly frequent monitoring of the patient's status and early determination regarding the need for a feeding tube is demanded of the clinician. Leder [84] wrote about the ease and value of serial FEES exams in moving the inpatient toward discharge as quickly as possible. Other authors have written about the cost effectiveness of a FEES program [37].

Rehabilitation strategies are more appropriate for patients who have potential for improvement. They can sometimes be trialed and taught during a FEES exam. The patient's ability to perform a Mendelsohn maneuver, a Super-supraglottic swallow or Effortful swallow can all be viewed and taught with endoscopy, although further instruction may need to occur outside of the endoscopy session.

FEES can also take advantage of biofeedback as the patient pairs his kinesthetic awareness to the visual signal seen on the monitor. Biofeedback has been shown to be one of the most effective modes to learn or improve a motor skill. It helps to speed up learning by reducing uncertainty of performance. The super-supraglottic swallow is much easier to learn with endoscopic feedback so that the patient learns how to close off his airway during a breath hold and to eliminate early spillage. A 'controlled swallow' where the patient learns how to eliminate spillage, can also be taught with biofeedback. Two publications where visual biofeedback was provided via endoscopy to dysphagic patients learning various swallowing strategies were Denk [85] with head and neck cancer patients and Manor [86] with Parkinson's patients. In both cases, the patients learning swallow strategies with biofeedback learned the strategies sooner and had better swallowing performance than the patients who did not receive biofeedback.

Use of FEES in Different Patient Populations

What population can benefit from FEES? A look at the literature suggests that many populations can benefit. A partial list includes extubated patients [87–90], head and neck cancer [91–96], stroke [28, 30, 97–99], tracheostomized patients [99, 100], Parkinson's disease [26, 86, 101, 102], vocal fold paralysis [103], myotonic dystrophy [104], critical illness polyneuropathy [105], osteophytes [106], myasthenia gravis [25], and progressive supranuclear palsy [27].

Special mention should be made of the pediatric population. Willging and colleagues were the first to write about using FEES with children [4, 20]. Over the years, the number of reports of using FEES with babies and children has escalated. One of the strongest proponents of FEES, Leder, wrote about using it with the pediatric population in general and with those who are ventilated [107, 108] Willette described using it with breastfeeding babies [109], while Reynolds wrote about its use in the NICU [110]. Two studies have compared results of FEES and MBS done consecutively and have all found high agreement in scoring spillage, residue, and especially for penetration and aspiration. [107, 111] FEES has several advantages; not exposing a baby or child to radiation, giving real food/liquid, and positioning the baby in a natural environment.

Contributions of Endoscopy to Our Understanding of Normal Swallowing and Dysphagia

FEES has broadened our understanding of normal swallowing and dysphagia in many ways. Some of these have already been discussed in this review, such as the research done on airway closure for swallowing (Van Daele [75]) and 'normal spillage times' when eating and drinking naturally [83]. A series of studies led by Butler on normal swallowing in healthy older adults has provided valuable

norms for normal spillage and frequency of penetration, and aspiration in aging adults [112–115].

Each tool used to evaluate dysphagia has unique properties that contribute to a broader knowledge of swallowing. Endoscopy makes unique contributions in a few domains: (1) It provides a direct, clear view of surface anatomy and the relationship of the hypopharyngeal structures. This has proven invaluable when assessing patients with head/neck cancer who have undergone surgery or radiotherapy. The bolus path is clearly visualized, and the clinician can alter head and neck postures to try to alter the direction taken by the bolus—to keep it out of the airway and find its way to the upper esophageal sphincter. (2) FEES can assess the patient's ability to swallow and respond to excess secretions. This bolus is not seen fluoroscopically, yet it is the most dangerous bolus to aspirate. (3) FEES can assess sensory function directly, by touching the arytenoid and looking for the laryngeal adductor reflex. Alternatively, it can assess sensory function indirectly by watching as a small amount of secretions or liquids pass over the laryngeal rim and head toward the glottis. The patient's response to this event tells us more than the formal sensory test ever could. (4) Finally, FEES can serve as a biofeedback tool for educating patients about the nature of their dysphagia and can be used to teach patients alternative ways to swallow. This is impractical with fluoroscopy.

The Future of FEES

Roles and Training

As dysphagia practices have emerged around the world, and as FEES has gained a prominent role as one of the key instrumental exams to be done, the role of otolaryngologists, other physicians, speech pathologists, and other allied health professionals in evaluating patients with suspected dysphagia has reflected the society and culture in which FEES is performed. The same is true for the Modified Barium Swallow procedure but to a lesser degree. Perhaps, because fewer radiologists have adopted pharyngeal swallowing as an area of interest, the MBS exam (in the US) is usually led by the speech pathologist, with the radiologist playing a supportive role. When deciding who should perform FEES, it becomes apparent that this is a more contested issue. It was developed by a speech pathologist in 1988 (Langmore) and in the US, the UK, and many other countries in Europe, the speech pathologist/therapist/logopedist takes the lead. It was put into the scope of practice for SLPs in the US in 2001 by the American Speech Language Hearing Association [116]. Several other ASHA position papers have been published since then, detailing

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