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Phoniatry

Comparison between videofluoroscopy, fiberoptic endoscopy and scintigraphy for diagnosis of oro-pharyngeal dysphagia

Confronto tra videofluoroscopia, endoscopia a fibre ottiche e scintigrafia per la diagnosi di disfagia oro-faringea

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SUMMARY

The purpose of this study was to compare videofluoroscopy (VFS), fiberoptic endoscopic evaluation of swallowing (FEES) and oro-pharyngo-oesophageal scintigraphy (OPES) with regards to premature spillage, post-swallowing residue and aspiration to assess the reliability of these tests for detection of oro-pharyngeal dysphagia. Sixty patients affected with dysphagia of various origin were enrolled in the study and submitted to VFS, FEES and OPES using a liquid and semi-solid bolus. As a reference, we used VFS. Both the FEES and the OPES showed good sensitivity with high overall values (≥ 80% and ≥ 90% respectively). The comparison between FEES vs VFS concerning drop before swallowing showed good specificity (84.4% for semi-solids and 86.7% for liquids). In the case of post-swallowing residue, FEES vs VFS revealed good overall validity (75% for semi-solids) with specificity and sensitivity well balanced for the semi-solids. OPES vs. VFS demonstrated good sensitivity (88.6%) and overall validity (76.7%) for liquids. The analysis of FEES vs. VFS for aspiration showed that the overall validity was low (≤ 65%). On the other hand, OPES demonstrated appreciable overall validity (71.7%). VFS, FEES and OPES are capable of detecting oro-pharyngeal dysphagia. FEES gave significant results in the evaluation of post-swallowing residues.

KEY WORDS: Dysphagia • Videofluoroscopy • Fiberoptic Endoscopic Evaluation of Swallowing • Oro-pharyngo-oesophageal Scintigraphy • Speech-language pathology

RIASSUNTO

L'obiettivo di questo studio era quello di confrontare la Videofluoroscopia (VFS), la valutazione endoscopica a fibre ottiche della deglutizione (FEES) e la scintigrafia oro-faringo-esofagea (OPES) per quanto riguarda la caduta pre-deglutitoria, il ristagno post-deglutitorio e l'aspirazione, al fine di valutare l'attendibilità di questi test nel rilevare la disfagia orofaringea. Sessanta pazienti, affetti da disfagia di varia origine, sono stati arruolati nello studio e sottoposti a VFS, FEES e OPES utilizzando un bolo liquido e uno semi-solido. Abbiamo usato la VFS come esame di riferimento. La FEES e la OPES hanno entrambe mostrato una buona sensibilità, con valori complessivi elevati (rispettivamente ≥ 80% e ≥ 90%). Il confronto tra FEES e VFS relativamente alla caduta pre-deglutitoria ha evidenziato una buona specificità (84,4% per i semi-solidi e 86,7% per i liquidi). Nel caso di ristagni post-deglutitori, il confronto tra FEES e VFS ha rivelato una buona validità complessiva (75% per i semi-solidi), con specificità e sensibilità ben equilibrate per i semi-solidi. Il confronto tra OPES e VFS ha dimostrato buona sensibilità (88,6%) e validità complessiva (76,7%) per i liquidi. Il confronto dei dati ottenuti tra FEES e VFS, relativamente all' aspirazione, ha evidenziato una bassa validità complessiva (≤ 65%). D'altra parte, la OPES ha mostrato una validità complessiva apprezzabile (71,7%). VFS, FEES e OPES sono in grado di rilevare la disfagia oro-faringea. La FEES ha fornito risultati significativi nella valutazione dei ristagni post-deglutitori.

PAROLE CHIAVE: *Disfagia • Videofluoroscopia • Valutazione endoscopica a fibre ottiche della deglutizione •Scintigrafia orofaringoesofagea • Foniatria*

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Introduction

Videofluoroscopy (VFS), fiberoptic endoscopic evaluation of swallowing (FEES) and oro-pharyngo-oesophageal scintigraphy (OPES) are all widely used tools for studying swallowing disorders in the oro-pharyngeal area. While VFS is still considered by speech-language pathologists to be the gold standard, there are numerous reports in the literature that emphasise the validity of the other two methods [1-5]. Accurate assessment of the oro-pharyngeal phase of swallowing is particularly important since this presents the greatest clinical risk for dysphagic patients: tracheo-bronchial

aspiration. Furthermore, early diagnosis of oro-pharyngeal dysphagia can prevent malnutrition and dehydration in the patient, as well as avoiding significant impairment to the quality of his life. In the literature there are numerous studies that compare the efficacy of the various diagnostic tools for detecting penetration and aspiration [6-15]. Some authors demonstrated a good agreement between VFS and FEES, especially regarding aspiration (82.3-90% agreement); the analysis of FEES vs. VFS showed that the sensitivity of FEES was 88% and specificity was overall lower, but was 92% for detection of aspiration [11 13 14]. In 2003, Rao et al. [15] studied sensitivity and specificity values for laryngeal penetration, tracheal aspiration and pharyngeal residue for both the VFS and FEES. When the VFS was used as the gold standard, sensitivity of the FEES for laryngeal penetration was 87%, aspiration 96% and pharyngeal residue 68%. Specificity of the FEES for laryngeal penetration and aspiration were both 100%, and pharyngeal residue was 98%. When the FEES was used as the gold standard, sensitivity of the VFS for laryngeal penetration and aspiration were both 100%, and pharyngeal residue was 96%. Specificity of the VFS for laryngeal penetration was 58%, aspiration 63% and pharyngeal residue 78% [15].

There are few data in the literature regarding the OPES. In 2004, Shaw et al. [5] calculated that the specificity of the OPES retention indices for liquid boluses is 100% in the oral area and 96% in the pharynx, while sensitivity in these areas is low (being 72% and 57%, respectively). More recently, Huang et al. [9] studied the correlation between OPES and VFS; scintigraphy parameters had good predictive value for VFS findings, with sensitivity, specificity, positive predictive values and negative predictive values between 70% and 95%. OPES had good sensitivity in detecting 91% of aspirations and 81% of penetrations and/or aspirations in VFS, while the specificity was lower [9].

There are few reports in the literature that take into account other parameters that are equally important for a precise definition of swallowing efficiency and, in particular, the degree of oro-pharyngeal dysphagia [5 8 9 16-18]. In fact, by assessing the pre-swallowing presence of a bolus in the pharynx, the presence and amount of residue in the hypo-pharyngeal area, we can more accurately estimate the efficacy of this oro-pharyngeal phase and consequently the risks involved in penetration and aspiration, even if these events are not immediate but later in time after the administration of the bolus [16 19].

These parameters (premature spillage, post swallowing residue and aspiration) can be assessed with all three of the above-mentioned methods; in this respect, we compared them to see if any one of these methods was better suited for overall clinical evaluation of the oro-pharyngeal phase of swallowing and if there was any correspondence among the various parameters studied with the three tests. In our study, the three methods (VFS, FEES and OPES) were performed on the same day.

Materials and methods

For this study we enrolled 60 dysphagic patients (22 females and 38 males; mean age 63.66 yrs ± 16.5 SD) who were referred to the unit for dysphagia studies of Pisa University Hospital between January and April 2014. The disorders behind the dysphagia were neurological in 34 (56.7%), post-surgical for head-neck cancer in 15 (25%) gastroenterological with pharyngeal-laryngeal reflux in 7 (11.6%) and pneumological with bronchial-pulmonary disease in 4 (6.7%). The mean onset of the dysphagia was 1.5 years (1.2 SD) prior to the study. All the patients enrolled in the study were collaborative and capable of maintaining good postural alignment. None had undergone any type of speech rehabilitation and none had to use either a NGFT or a PEG. Furthermore, none of the patients referred an allergy to drugs, to suffer from favism or to be pregnant. All patients were submitted to FEES, VFS and OPES performed with both a liquid bolus (5 cc water) and a semi-solid one (5 cc jellied drink, Bevanda Gelificata, Novartis S.A.®).

The first test was always performed with the FEES since these were first-time patients in our dysphagia surgery in the ENT, Audiology and Phoniatric Unit. Moreover, the operators who performed and reported the results of the individual tests (FEES, VFS and OPES) were unaware of the results of the other investigations. The parameters we took into account for all three of the tests were: presence of premature spillage, presence and amount of post-swallowing residue in the hypo-pharyngeal area, presence of tracheo-bronchial aspiration (Table I) [20-23].

Informed consent was obtained from all participants and the study was approved by the Ethical Research Committee of the University Hospital of Pisa.

Fiberoptic endoscopic evaluation of swallowing (FEES)

FEES is performed with a flexible fiberoptic rhinopharyngolaryngoscope (Olympus ENF-P3) connected to a CCD camera and colour monitor and recorded digitally on a Digital Swallowing Workstation (Kay Pentax Ltd®, Montvale, NJ, USA). The examination was carried out by two speech-language pathologists and each patient was administered two or more semi-solid (jellied drink, Bevanda Gelificata, Novartis S.A.®) or liquid boluses (water marked with methylene blue for easy detection), swallowing 5 cc of each type of bolus. Evaluation of pre-swallowing penetration and aspiration was given Score 0 if it was absent and Score 1 if it was present. The amount of the residue (pooling amount) in the hypopharynx was calculated against the Farneti pooling-score scale [21 22] (Table I).

Videofluoroscopy (VFS)

The digital fluoroscopy examinations were performed with a Clinodigit Compact Xframe Italray device. The digital images were acquired by filming at a frame rate of

Table I. OPES - VFS - FEES Ratio Score.

	Premature spillage		Aspiration	
ABSENT	0		0	
PRESENT	1		1	
Hypopharyngeal residue	**None**	**Mild**	**Moderate**	**Severe**
VFS[20]	0 (< 3%)	1 (≥ 3 to < 25%)	2 (≥ 25 to < 55%)	3 (≥ 55%)
OPES[23]	0 (< 5%)	1 (≥ 5 to < 20%)	2 (≥ 20 to < 40%)	3 (≥ 40%)
FEES[21-22]	0	1	2	3

30/sec, which was sufficient for recording the swallowing act. Acquisition resolution was 3001x3001x14 bit.
Digitalised imaging permits the creation of a PACS (picture archiving and communication system), which is a computerised system where the images are uploaded, together with the relative data supplied by the various diagnostic tools available in the hospital, thus allowing the images to be archived and shared. Furthermore, the PACS permits viewing information concerning any previous investigation the patient has been submitted to whenever a new examination has become necessary. Patients are initially positioned in the lateral view, and regions of visualisation include the oral cavity, pharyngeal cavity larynx and cervical oesophagus. 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 [24]. Dynamic recording at a minimum of 30 video frames/sec is essential for detecting the rapid movements and bolus flow events associated with oropharyngeal swallowing. The possibility to perform an accurate evaluation with freeze-frame and slow motion capability must be allowed [24].
An image is enlarged on the neck region of the patient in an orthostatic latero-lateral position, and the contrast medium is administered. The contrast medium used was Prontobario HD (Bracco®): the packaging supplied contains 340 g powder for oral suspension, 98.45% barium sulphate. The powder is diluted in 65 ml of water for the liquid consistency and in 30 ml of water for the semi-solid bolus; for each density, the patient is invited to take three sips of 5 cc.
The fluoroscope is activated at the time of administration of the contrast bolus and is deactivated immediately after the bolus has passed through the upper oesophageal sphincter in order to minimise exposure. The total radiation exposure it is fairly constant and is similar to the amount typically encountered in an upper gastrointestinal series. The examination may be extended depending on nature and severity of the patient's swallowing problem and condition, although the goal of minimising radiation exposure while maximising clinical results is consistently maintained [24].

Oro-pharyngo-oesophageal scintigraphy (OPES)
In the OPES investigation, the patient's face is in an 80° oblique projection on front of a single rectangular headed large-field-of–view (LFOV) gamma camera equipped with a low energy-high resolution (LEHR) parallel hole collimator using a 140 KeV (± 10%) energy window. Prior to the marked bolus, patients were given 5 cc of the non-marked bolus to allow them to practice taking it before the actual investigation. The patient is administered a single bolus of 5 cc of water marked with 37 MBq (1 mCi) of ^{99m}Tc nanocolloid (Nanocoll-Amersham®, UK). Eight images per sec (0.125 sec/frame) are acquired for one min, by means of dynamic acquisitions (with a 64 x 64 matrix and zoom at 1), including the oral region as far as the epigastric area within the imaging field. The pharyngeal region of interest (ROI) was that between the oral cavity and the external reference corresponding to the pharyngo-oesophageal transition. An external marker was positioned at mandibular angle level and another one at the level of the cricoid [25]. Two sec after the start, the patient is invited to take the liquid bolus in one swallow. At the end of the test, a static image lasting 60 sec is acquired, with the patient still in the same position, to evaluate any possible tracheo-bronchial aspiration.
After an interval of 30 min, the procedure is repeated, but this time with a semi-solid bolus marked with 37 MBq (1 mCi) of ^{99m}Tc nanocolloid. The acquisitions were obtained with the same method as with the liquid bolus.

Statistical analysis
Analyses were carried out with the SPSS statistical package (version 20). Descriptive statistics were performed to describe a sample characteristic (age, gender and the time of onset of dysphagia). Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and validity, for FEES and OPES, were determined by comparing to the gold standard (VFS), both in the liquid and semi-solid tests. Furthermore, with the same indices (sensitivity, specificity, PPV, NPV and validity), the OPES method was compared to FEES, considering the latter as the gold standard (Table II).

Table II. Results of a diagnostic test presented as a 2x2 table.

Result of diagnostic tests	Results of Gold Standard Test	
	Disease present	Disease absent
Test positive	True positive (a)	False positive (b)
Test negative	False negative (c)	True negative (d)

Sensitivity = a/a+c
Specificity = d/b+d
PPV = Sensitivity π/ Sensitivity* π+(1- Specificity)*(1- π)*
NPV = Specificity(1- π)/ Specificity*(1- π)+(1- Sensitivity)**
Validity = (True positive+True negative)/(True positive+True negative+False positive+False negative).

Results

The first evaluation carried out was to assess the ability of the three tests (VFS; OPES; FEES) to detect the presence of swallowing alterations. As a reference value, we initially used the VFS since this is the gold standard. FEES showed good sensitivity with both semi-solids (85.2%) and liquids (80.4%), and the overall validity of the test was 83.3% and 80%, respectively. OPES also demonstrated good sensitivity with semi-solids (96.3%) and liquids (94.1%), with an overall validity of the test of 93.3% and 90%, respectively (Table III and Table IV).

The comparison between OPES and FEES in the detection of dysphagia gave high sensitivity values (> 97.9%) and a high overall validity (> 83%) for both densities considered.

We then evaluated the parameters of the study on oropharyngeal dysphagia: premature spillage, hypopharyngeal residue and aspiration.

The premature spillage parameter in the case of FEES vs VFS showed good specificity with both semi-solids (84.4%) and liquids (86.7%), but sensitivity values were low (both equal to 60%) and the overall validity of the test was 78.3% in the case of semi-solids and 80% with liquids (Table III and Table IV). OPES showed the highest specificity (95.6% with both semi-solids and liquids) and an overall validity at 81.7% for semi-solids and 85% for liquids, but very low sensitivity values (40% and 53.3%, respectively).

The comparison between OPES and FEES gave a specificity of 86% for liquids and 95.5% for semi-solids, but sensitivity was low (37.5%).

Post-swallowing hypopharyngeal residue. The FEES vs. VFS assessment gave a good overall validity (75%), with the specificity and sensitivity values being well balanced in the case of semi-solids; the overall validity for the liquids was lower (65%). OPES vs. VFS showed a low overall validity in the case of semi-solids (43%), while in the

Table III. The sensitivity, specificity, predictive positive value (PPV), predicitive negative value (PNV) and validity in the three tests (VFS; FEES; OPES) with semi-solid boluses.

			Semisolid		
	Sensitivity	Specificity	PPV	NPV	Validity
FEES vs VFS	85.2	66.7	95.8	33.3	83.3
OPES vs VFS	96.3	66.7	96.3	66.7	93.3
OPES vs FEES	97.9	41.7	87.0	83.3	86.7
			FEES vs. VFS		
	Sensitivity	Specificity	PPV	NPV	Validity
Premature spillage	60.0	84.4	56.3	86.4	78.3
Hypopharyngeal residue	75.6	73.3	89.5	50.0	75.0
Aspiration	33.3	87.9	69.2	61.7	63.3
			OPES vs. VFS		
	Sensitivity	Specificity	PPV	NPV	Validity
Premature spillage	40.0	95.6	75.0	82.7	81.7
Hypopharyngeal residue	33.3	73.3	78.9	26.8	43.3
Aspiration	63.0	78.8	70.8	72.2	71.7
			OPES vs. FEES		
	Sensitivity	Specificity	PPV	NPV	Validity
Premature spillage	37.5	95.5	75.0	80.8	80.0
Hypopharyngeal residue	36.8	77.3	73.7	41.5	51.7
Aspiration	76.9	70.2	41.7	91.7	71.7

Table IV. The sensitivity, specificity, predictive positive value (PPV), predicitive negative value (PNV) and validity in the three tests (VFS; FEES; OPES) with both liquid boluses.

			Liquid		
	Sensitivity	**Specificity**	**PPV**	**NPV**	**Validity**
FEES vs VFS	80.4	77.8	95.3	41.2	80.0
OPES vs VFS	94.1	66.7	94.1	66.7	90.0
OPES vs FEES	97.7	47.1	82.4	88.9	83.3
			FEES vs. VFS		
	Sensitivity	**Specificity**	**PPV**	**NPV**	**Validity**
Premature spillage	60.0	86.7	60.0	86.7	80.0
Hypopharyngeal residue	61.4	75.0	87.1	41.4	65.0
Aspiration	37.0	87.9	71.4	63.0	65.0
			OPES vs. VFS		
	Sensitivity	**Specificity**	**PPV**	**NPV**	**Validity**
Premature spillage	53.3	95.6	80.0	86.0	85.0
Hypopharyngeal residue	88.6	43.8	81.3	58.3	76.7
Aspiration	51.9	72.7	60.9	64.9	63.3
			OPES vs. FEES		
	Sensitivity	**Specificity**	**PPV**	**NPV**	**Validity**
Premature spillage	80.0	86.0	53.3	95.6	85.0
Hypopharyngeal residue	96.8	41.4	63.8	92.3	71.7
Aspiration	71.4	71.7	43.5	89.2	71.7

case of liquids the sensitivity was good (88.6%), as was the overall validity (76.7%). The results of the comparison between OPES and FEES were poor, showing that the best results are obtained with the VFS test.

Aspiration. FEES vs. VFS demonstrated a low overall validity of the test both with semi-solids (63.3%) and liquids (65%). In contrast, OPES showed a fairly good overall validity (71.7%), with a balance between sensitivity and specificity values for both the densities tested.

The number and relative percentage of the subjects in the study who were positive (pathological) for premature spillage, hypopharyngeal residue and aspiration in the FEES, VFS and OPES tests with liquid and semi-solid boluses, respectively, are given in Table V.

Discussion

For years, VFS has been considered by speech-language pathologists as the gold standard test for studying oro-pharyngeal dysphagia. Recently, however, its role has been debated, principally because of the introduction of other diagnostic tools for studying swallowing in the clinical field, such as videoendoscopy (FEES) and oro-pharyngo-oesophageal scintigraphy (OPES) [2 3 5 23-30]. Hence, VFS, FEES and OPES are three important tests for the early detection of dysphagia and all three should be taken into account when oro-pharyngeal dysphagia is suspected and/or when it is necessary to programme strict follow-up [1 5 17]. The importance of early diagnosis of dysphagia and the consequent care of the patient is linked with the need to

Table V. The number and relative percentage of the subjects in the study who resulted to be positive (pathological) for premature spillage, hypopharyngeal residue and aspiration in the FEES, VFS and OPES tests with liquid and semi-solid boluses, respectively.

		Liquid	
	FEES	**VFS**	**OPES**
Premature spillage	15/60 (25%)	15/60 (25%)	10/60 (16.7%)
Hypopharyngeal residue	31/60 (51.7%)	44/60 (73.3%)	48/60 (80%)
Aspiration	14/60 (23.3%)	27/60 (45%)	23/60 (38.3%)
		Semi-solid	
	FEES	**VFS**	**OPES**
Premature spillage	16/60 (26.7%)	15/60 (25%)	8/60 (13.3%)
Hypopharyngeal residue	38/60 (63.3%)	45/60 (75%)	19/60 (31.7%)
Aspiration	13/60 (21.7%)	27/60 (45%)	24/60 (40%)

prevent complications due to malnutrition, dehydration and ab ingestis pneumonia [6]. Furthermore, oro-pharyngeal dysphagia can drastically alter the patient's quality of life, especially during meals.

There are many reports in the literature that compare FEES with VFS, OPES with VFS and OPES with FEES (both in normal and dysphagic subjects) [5 8-10 14 16-18 31]. In particular, there is no report in the literature of a study that statistically compares the results obtained from the three examinations performed at the same time (FEES vs. VFS vs. OPES) in the same group of patients, either to achieve a correct diagnosis of oro-pharyngeal dysphagia or to evaluate individual swallowing parameters such as premature spillage of the bolus, post-swallowing residue and tracheo-bronchial aspiration.

In this study, we compared the results obtained with these three diagnostic tools using liquid and semi-solid boluses to assess the reliability of these tests in the detection of oro-pharyngeal dysphagia in patients affected with swallowing disorders of various origins.

The results revealed that both FEES and OPES performed with both of the densities show good sensitivity and overall validity compared to the gold standard (VFS), and that sensitivity and overall validity values were high (97.9% and 86.7%, respectively), demonstrating that these two diagnostic tools (OPES and FEES) are essentially superimposable in the detection of dysphagia. OPES objectively measures and quantifies bolus transit, bolus residues and tracheobronchial aspiration, and allows a simultaneous qualitative analysis of each swallow by means of activity/time curves. Combining OPES systematically with FEES without performing VFS might actually be sufficient in many clinical situations [32-35].

Thus, all three of these tests, FEES, VFS and OPES, are capable of supplying an accurate diagnosis of oro-pharyngeal dysphagia.

However, when we take into account the single parameters individually, we notice that in the case of premature spillage, VFS is still the test to be considered the gold standard. FEES was statistically better than OPES because the videoendoscopic evaluation of this parameter is seen directly by the observer and even the penetration of small amounts of liquid or semi-solid boluses is clearly visible. In the OPES test, on the other hand, small quantities of premature spillage can escape the attention of the observer during the evaluation since the main aim is to delineate the regions of interest (ROI). Our results indicate that VFS and FEES are tests to refer to for demonstrating premature spillage, while the OPES is less precise for this parameter. Other authors however have shown a good correlation between OPES and VFS for this parameter [9].

The evaluation of post-swallowing residue with FEES gave better results than with OPES, because the videoendoscopic method permits a direct view of the hypopharyngeal region and residues are therefore clearly visible and easily quantified even when they are negligible. However, a report in the literature found that there is a possibility that FEES might over-estimate pharyngeal residue compared to VFS, and this must be taken into account when managing dysphagia patients [16]. On the other hand, the scintigraphic examination (OPES) results were less precise than the other two tests in demonstrating and calculating post-swallowing residue. This poor accuracy probably derives from the fact that this test fails to supply anatomical definitions and that it has to construct the regions of interest (ROI) on the images acquired, a factor that makes OPES operator-dependent. In the literature, however, there are some reports of a good correlation between OPES and VFS concerning the post-swallow pharyngeal residue parameter, proving the usefulness of the scintigraphic examination even for this parameter [5 9 17], but our data do not agree with these results.

According to the results of our statistical analysis of tracheo-bronchial aspiration, VFS appears to define it very well even if its quantification is nevertheless evaluated well by OPES. Our results are also in agreement with the latest data published in the literature, which indicate the good sensitivity of scintigraphy in detecting penetration and/or aspiration [9]. As far as FEES is concerned, however, the data in the literature point out that videoendoscopic examination of swallowing can over-estimate penetration and aspiration of the bolus, producing important clinical and rehabilitative implications as a consequence [10]. Nevertheless, other studies stress that FEES is useful for evaluating episodes of aspiration, since the test is non-invasive and is inexpensive [14]. The results of the FEES test in our study on aspiration were less accurate than those obtained with the other two examinations, especially in cases of aspiration of small quantities of bolus.

Conclusions

Our study leads us to conclude that the VFS, FEES and OPES tests are all capable of detecting oro-pharyngeal dysphagia, whichever disorder is at the basis of it. Nevertheless, VFS must still be considered by speech-language pathologists as the gold standard since it supplies values that are more reliable than those obtained with the other two tests, at least as far as the swallowing parameters we took into account are concerned. Furthermore, VFS gives more information about the physiology of pharyngeal phase of swallowing and is particularly useful in cases when the swallowing mechanism is altered during the oral and/or oesophageal phase [16 31]. FEES gave results that were statistically significant compared to VFS and OPES, particularly in the evaluation of post-swallowing residues in the hypopharyngeal region, residues that become of important predictive value even of the risk of aspiration [16 17 21] and which we believe to be the most important (together with aspiration) of the three parameters taken into consideration.

In addition, as reported in the literature, FEES has a great advantage over VFS in that it uses real food during the test and allows a better view of the larynx movement [16]. Therefore, on the grounds of these considerations and our results, we maintain that FEES should always be considered as a valid test for studying swallowing, particularly since it is able to replace the VFS for investigating oropharyngeal dysphagia, and that it should be performed first of all when it is not possible to use VFS. Other advantages of the FEES test are that it is simple to perform, it is well tolerated by the patient and its use is much more economical than the other two methods [36]. Moreover, since FEES does not expose the patient to radiation, unlike VFS and OPES, it can be repeated several times even at brief intervals for accurate follow-up of dysphagia, perhaps during rehabilitation with speech therapy [37]. However, it must be remembered that OPES exposes the patient to very low dosages of radiation and that for this reason it can be used instead of VFS for monitoring swallowing disorders during speech therapy and rehabilitation [38-39]. On the other hand, we believe that OPES is to be considered a more complementary type of test. In this respect, this test in our study was more useful than VFS and FEES for semi-quantitative evaluation of tracheo-bronchial aspiration, permitting us to obtain percentages of aspiration that would have been difficult to quantify with the other methods.

Hence, our study has shown how VFS can be considered as the test of choice for assessing pre-swallowing spillage and tracheo-bronchial inhalation, while FEES is the test of choice for studying residue. If these three parameters are to be evaluated from a semi-quantitative point of view, then OPES can be used together with the other two as a complementary test.

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