Round Table S.I.O. National Congress

Role of videofluoroscopy in evaluation of neurologic dysphagia

Il ruolo della videofluoroscopia nella diagnosi della disfagia neurologica

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SUMMARY

For many years, videofluoroscopy was considered the gold standard for studies on swallowing disorders, and only recently has its role been challenged, due primarily to the widespread use of videoendoscopy in the evaluation of dysphagia. Albeit, videofluoroscopy still maintains its key role in this area and, in particular, in studies on dysphagia of neurological origin, on account not only of the possibility, with this procedure, to achieve complete and dynamic evaluation of all phases of deglutition, but also the high sensitivity and specificity in revealing the presence of inhalation. Aim of the present investigation was to analyse the technical procedure of videofluoroscopy and the principal indications in the study of dysphagia of neurological origin, in the attempt to reveal the advantages and disadvantages occurring in this examination, also with respect to other methods adopted in the evaluation of dyphagia. In conclusion, at present, no instrumental examination can be defined as ideal for the study of swallowing, but it can be seen that, with each of these procedures, the information forthcoming is actually complementary, thus achieving the aim to proceed as correctly and rapidly as possible, with the management of patients with dysphagia.

KEY WORDS: Swallowing • Dysphagia • Aspiration • Videofluoroscopy • Fiberoptic endoscopy

RIASSUNTO

La videofluoroscopia è stata considerata per anni il gold standard per lo studio delle alterazioni della deglutizione. Solo recentemente il suo ruolo è stato messo in discussione, principalmente a causa della diffusione che ha trovato la videoendoscopia nella valutazione della disfagia. La videofluoroscopia mantiene comunque il suo ruolo chiave in questo campo ed in particolare nello studio della disfagia di origine neurologica, grazie soprattutto alla possibilità che essa offre di valutare in modo completo e dinamico tutte le fasi della deglutizione e alla sua alta sensibilità e specificità nell'evidenziare la presenza di inalazione. In questo lavoro saranno analizzate le modalità di esecuzione della videofluoroscopia e le sue principali indicazioni nello studio della disfagia di origine neurologica, nel tentativo di evidenziare vantaggi e svantaggi presentati da questo esame, anche in rapporto alle altre metodiche utilizzate nella valutazione della disfagia. In conclusione attualmente nessun esame strumentale può essere definito come ideale per lo studio della deglutizione, ma esiste piuttosto una complementarietà tra le informazioni fornite da ciascuno, nell'obiettivo di ottenere una corretta e precoce presa in carico del paziente affetto da disfagia.

PAROLE CHIAVE: *Deglutizione • Disfagia • Aspirazione • Videofluoroscopia • Endoscopia*

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Introduction

Dysphagia caused by neurological disorders involves, primarily, the first two phases of swallowing, and, therefore, it is defined as oropharyngeal dysphagia. It is a frequently encountered problem with a marked social impact, if taking into consideration that it has been estimated that, in 2010, in the United States of America, 16,500,000 subjects will require specific treatment for dysphagia [1]. This is a deficit that follows the course of the initial disorder, thus, in some cases, it presents with an acute onset and a seemingly favourable course, as in the case of stroke and traumatic brain injury, whilst in others, the course is chronic and progressively presents a more serious behaviour, as in the neurodegenerative diseases. In both cases, dysphagia is associated with an increase in the risk of aspiration pneumonia, malnutrition and dehydration, which lead to an increase in morbidity and mortality of the patients affected, as well as a deterioration in quality of life and a marked increase in public health spending. Rapid diagnosis and management of the swallowing disorder is, therefore, mandatory and should be aimed at: early identification of those patients with dysphagia presenting risk of aspiration; exclusion of the presence of structural alterations of the organs involved in swallowing; characterization of the alteration

of the swallowing mechanism responsible for the dysphagia; indication needs to suspend oral feeling and to adopt other alternatives for feeding, which in most cases is performed by means of percutaneous endoscopic gastrostomy (PEG), or, on the other hand, defining the right time to recommence oral feeding; programming of the specific therapeutic strategy, which includes the choice of the type of food to be given and/or planning of the rehabilitative logopaedic treatment.

Videofluoroscopy (VFS) or modified barium swallow has, for the last ten years, been considered the instrumental examination of choice in the study of swallowing, in addition to clinical history and bedside assessment. Study of swallowing using cineradiography, was first proposed, in 1965, by Donner & Siegel, who recognized its usefulness in the study of dysphagia caused by neuromotor disorders [2]. This technique has since been re-elaborated and improved, in particular by Logemann, which greatly contributed to further knowledge regarding the physiopathology of swallowing, with fundamental repercussions on the diagnosis and treatment of dysphagia [3 4]. The examination, which consists in recording fluoroscopic images which appear on the monitor during intake by the patient of a radio-opaque bolus, enables a precise evaluation to be made, not only of the morphological features but also, and above all, the dynamics of the swallowing act, including its three phases: oral, pharyngeal and oesophageal.

Even if, over the years, various instrumental investigations have been used alongside VFS, first of which videoendoscopy, but also oro-pharyngeal scintigraphy, echography, manometry which have been widely used in studies on swallowing, VFS still maintains a determinant role in achieving more detailed diagnostic data concerning swallowing disorders [5 6].

In the present report, based upon an analysis of the more recent literature, attention will be focused not only on the technical procedures used in this investigation, including the indications, in particular, in dysphagia of neurological origin, but also the advantages and limits, also compared to other instrumental examinations currently available for the specialist.

Technical procedure

VFS is a radiological investigation based upon the recording of fluoroscopic images appearing on the monitor of an X-ray machine, whilst the patient is swallowing a radio-opaque bolus. The equipment required to perform the investigation comprises a fluoroscopic tube large enough to include images of the oral cavity, pharynx, larynx, and upper oesophagus, as well as a high resolution video recording system. The possibility to be able to see the recorded images at any time during the course of the examination is fundamental considering that the swallowing action occurs in an extremely short time (approximately 2 seconds), thus making immediate analysis very difficult. Compared to cineradiography, which consists in a simple cinematographic recording on tape, VFS presents a series of advantages represented by less exposure to radiation and the possibility to see the recorded images again immediately, even while the examination is still being performed. The disadvantage consists, on the other hand, in the less frequent acquisition of the images with VFS compared to cinematography, 25-30 images/sec compared to 50-80 images/sec, which results in a less temporal resolution of the examination, which, nevertheless, is still adequate for the dynamic analysis of the swallowing act. The examination is performed by a radiologist, preferably in the presence of a phoniatric specialist and/or logopaedist.

VFS should be performed with the patient in a standing or sitting position, not only on account of the way in which the equipment is set up but also in order to place the patient in as close as possible to a physiological position for the swallowing act. The examination generally begins with the latero-lateral view, which allows identification of the reference points, namely, the cervical rachis, the prevertebral soft tissues, the tongue base, the hyoid bone and the larynx. These structures can be studied either at rest or whilst performing a dry swallow.

The next phase consists in administering a series of radio-opaque boluses, to the patient, represented by preparations of varying consistency opacified with contrast media and, if possible, made to taste pleasant in order to encourage the patient to take them. In theory, when performing this examination it is worthwhile attempting, as far as possible, to follow a standardized procedure as far as concerns the type of bolus given (rheological characteristics and quantity) which will be useful when comparing and repeating future examinations; albeit, due to the wide variety of clinical cases studied this cannot always be applied and it is, therefore, necessary to use personalised procedures. Usually, the examination begins with the administration of barium of liquid consistency, but sometimes it is better to begin using the consistency which is easier for the patient to swallow and which offers greater safety margins as far as concerns the risk of inhalation; usually this consists of a semi-solid consistency. The quantity administered begins with 5 or 10 ml, and the administration is usually repeated at least twice for each consistency and quantity. In those cases in which there is strong suspicion of the presence of inhalation, it is advisable to begin with the administration of the minimum quantity of boluses, for example 2 ml, in order to avoid the risk of inhalation of greater quantities of the contrast medium, particularly in the absence of a valid cough. If no signs of inhalation are observed, the examination is continued with the administration of boluses of variable consistency: liquid, semi-liquid and solid. For the latter, a biscuit or piece of toasted bread can be used, or as an alternative a “Marshmallow”, a sweet characterized by the elastic jelly-like consistency, dipped in barium. Currently available, on the market, are specific “ready for use” preparations, all containing the same concentration of sulphate barium, but varying in consistency and which have been made palatable (Varibar, E-Z-EM, Westbury, NY, USA). Use of these products offers the advantage of greater standardization of the tested consistencies as well as a better guarantee of reproducibility of the examination. Furthermore, Varibar is formulated with a concentration of barium which minimally coats mucosal surfaces, which, theoretically, results in a more accurate diagnosis of the oral and/or pharyngeal stasis [7].

As already pointed out, first of all, registration in a latero-lateral position is necessary: this plane offers the possibility to evaluate the passing of the bolus from the oral cavity towards the pharynx and subsequent passing into the oesophagus by way of the upper oesophageal sphincter (UES), analysing the movements of the mandible, tongue, *velum palati,* pharyngeal wall, hyoid bone, epiglottis. The main endpoints of the oral phase for deglutition effectiveness definition are: labial competence; lingual control: efficacy of the tongue in pushing the bolus towards the pharynx; palatoglossal closure: if impaired, the bolus can fall into the pharynx before triggering of the pharyngeal phase of swallowing; presence of fractional deglutition: the patient has to swallow the bolus in several times, because of the lack of efficacy of tongue propulsion; residue in the oral cavity at the end of the oral phase of deglutition. As far as concerns the pharyngeal phase, the principal endpoints for swallowing effectiveness assessment are: presence of nasopharyngeal regurgitation, due to inadequate palato-pharyngeal closure; triggering of the swallowing reflex, due to the passage of the bolus by the point where the jaw meets the base of the tongue; hyoid and laryngeal elevation; epiglottal tilting; residue in the pharyngeal cavity (glosso-epiglottal valleculae and pyriform sinuses) at the end of swallowing; abnormalities in the UES opening and in the coordination of the same with the pharyngeal phase of deglutition. But above all, the latero-lateral projection offers the possibility to reveal the presence of the passing of the contrast medium into the airways and to distinguish between penetration, defined as the passage of bolus into the laryngeal vestibulum above the vocal cords (Fig. 1) and aspiration that occurs when the bolus goes through the vocal cords into the inferior airways (Fig. 2). Furthermore, with VFS in the latero-lateral projection, it is possible to differentiate inhalation on the basis of the temporal relationship with the pharyngeal phase of deglutition during which the following occurs: pre-deglutitory inhalation, when it takes place before the triggering of pharyngeal phase, as a result of posterior oral spillage or delay in swallowing initiation; intra-deglutitory inhalation, when it occurs during the pharyngeal phase, due to an incomplete closure of the larynx; post-deglutitory inhalation, when it occurs at the end of the pharyngeal phase, due to residue in the hypopharynx, whether or not associated with inadequate UES opening.

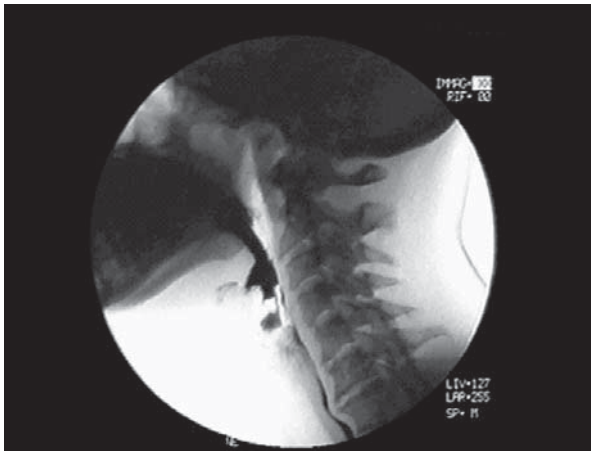

Fig. 1. Lateral view of swallow during VFS, showing penetration of contrast medium above vocal cords.

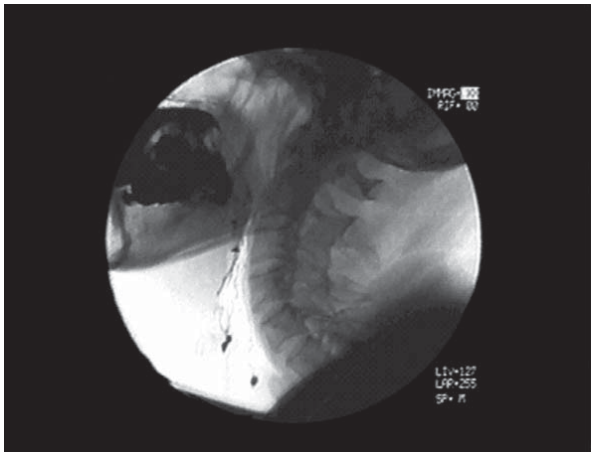

Fig. 2. Lateral view of swallow during VFS, showing penetration of contrast medium below vocal cords (inhalation).

The examination is generally concluded with an antero-posterior projection which enables to reveal the asymmetry of an eventual oral and/or pharyngeal stasis of the bolus.

The presence of the logopaedist, whilst carrying out the examination, as already pointed out, is highly recommended, not only to guide the radiologist to what, in effect, one wants to reveal when performing VFS, but also because, by means of a modification and a more detailed examination procedure, it is possible to obtain information vital to the planning of the rehabilitation programme. In fact, during VFS, it is available, not only to identify the consistency more easily swallowed by the patient and with less risk of inhalation, but also to test the efficacy of certain manoeuvres adopted during the logopaedic rehabilitation treatment of deglutition, such as postural strategies based upon modification of the position of the head during deglutition. Furthermore, in patients who have already commenced a programme of logopaedic rehabilitation of deglutition, it is possible by means of VFS to evaluate the effect of specific active manoeuvres, such as Mendelson manoeuvre, supraglottic deglutition and super-supraglottic deglutition.

VFS offers the possibility to measure certain temporal parameters of the various phases of deglutition, in particular, oral transit time (OTT), defined as the time elapsed since the bolus starts moving inside the mouth until the head of the bolus passes into the pharynx beyond the base of the tongue, and the pharyngeal transit time (PTT), defined as the time elapsed since the head of the bolus goes past the base of the tongue until the tail of the bolus goes through the UES. On the basis of the measurement of these phases, an overall evaluation index of the efficacy of the swallowing act has been introduced, known as Oropharyngeal Swallowing Efficiency (OPSE) [8]. This is obtained by calculating the relationship between the difference between the quantity of bolus administered and the percentage aspired or remaining in the oral cavity or pharynx and the sum of the oral and PTTs. The difficulty encountered in calculating this parameter lies, above all, in the fact that quantification of the percentage of bolus inhaled or remaining, is somewhat approximate,

inasmuch as, first of all it is based exclusively upon the personal judgement expressed by the individual operator and, moreover, requires measuring a parameter presenting tridimensional characteristics by means of an examination that allows an exclusively bidimensional view [9].
In contrast with this observation, Logemann et al. [10] recently reported the results of a study, in which the measurements related to the oral and pharyngeal residue were compared by means of oropharyngeal scintigraphy, which is currently held to be the only examination feasible to precisely evaluate oral and pharyngeal residue [11], and by means of VFS observation. A comparison between the results of the two examinations, whilst confirming the better results obtained with scintigraphy, as far as concerns the precision of the quantitative evaluation of the swallow residue, showed, in conclusion, that VFS, if performed and analysed by an expert, is a reliable examination with which to obtain precise measurements of the above-mentioned parameters [10].
VFS is not an easy examination to interpret, requiring considerable experience on the part of the examiner and improved by group discussion between assessors. Regarding the inter- and intra-individual variation in the interpretation of VFS, according to reports in the literature, the percent agreement between the evaluation of two or more operators varies between 76% and 92% [12 13], with higher values as far as concerns the finding of the presence of inhalation, but lower as far as concerns the finding of functional alterations of the swallowing acts [14]. Discordant results have been reported also with respect to the intra-individual variation in the interpretation of the examination, with increasing values of disagreement showing a direct relationship with the level of experience of the examiner [14 15].

Indications and clinical applications

The goals of VFS include: assessment of efficacy and safety of deglutition, characterization of biomechanical deglutition impairment and evaluation of effectiveness of treatment strategies. VFS is, therefore, indicated in the study of oro-pharyngeal dysphagia, when with only clinical examination doubts remain regarding the presence, or not, of inhalation, when it is impossible to define the site and mechanism of the alteration of deglutition, or it is necessary to better evaluate the efficacy of specific postures or compensatory maneouvres, aimed at correctly programming the rehabilitation strategies.
VFS appears to be particularly indicated in all those cases in which the presence of silent aspiration is suspected. In this regard, it should not be forgotten that silent aspiration refers to the passage of swallowed material into the airways, without the appearance of clear clinical signs, represented primarily by coughing or voice change. Silent aspiration, which occurs as a physiological event also in normal subjects while sleeping, appears to be particularly frequent in patients presenting dysphagia of neurological origin, reaching 40-60% of subjects according to reports in the literature. The main cause is lack of adequate reflex of the cough, a consequence of the weakness at peripheral level or lack of coordination at central level of the pharyngeal muscles, or reduced pharyngolaryngeal sensitivity [16]. Not recognizing silent aspiration can lead to serious respiratory complications, therefore in all those cases in which the presence of silent aspiration is suspected, instrumental evaluation of deglutition is recommended.
Let us now take a look at the indications proposed for performing VFS in the principal neurological disorders responsible for dysphagia.

Cerebrovascular accident (stroke)

Stroke represents the most frequent cause of neurological dysphagia. The severity and characteristics of dysphagia are strictly related to the site, type (ischaemic *vs.* haemorrhagic) and extent of the neurological lesion, but also to age and general conditions of the patient. Dysphagia is associated with an increased risk of developing aspiration pneumonia: in the literature, it has been calculated that 50,000 deaths/year in the United States are caused by aspiration pneumonia resulting from a stroke [17]. Diagnosis and rapid treatment of dysphagia is, therefore, mandatory to reduce the incidence of complications (pneumonia, dehydration, undernutrition) with, consequently, a reduction in the death rate, but also length of hospital stay and healthcare expenditure [18]. Data reported in the literature regarding the incidence of dysphagia in stroke vary considerably, ranging, indeed, between 19% and 81% [19 20], depending upon the methods used in the diagnostic workup, the period elapsing from the diagnosis and the stroke and the type of lesions studied. In general, the incidence of dysphagia is greater in lesions localised in the brainstem, compared to hemispheric lesions. Dysphagia tends towards a spontaneous resolution in the course of the early weeks after onset, in a large number of cases, > 50% according to most Authors [21 22], albeit according to others, the percentage of patients in whom, 6 months after the stroke, an impaired deglutition is still present, is fairly high (between 11% and 50%) [23].
Classically, the first step in the diagnostic approach to dysphagia is of a clinical nature, by means of screening tests, for example performing dry deglutitions or administration of minimum quantities of water or semiliquids and direct observation of the patient. The next step, in dubious cases, is the clinical evaluation performed by the specialist (bedside examination). Albeit, the clinical assessment is rarely the final step in the dysphagia evaluation process. The limited collaboration, associated often with other deficits of a behavioural and communicative nature presented by many of the patients examined, further contributes to the difficulties encountered in performing a reliable clinical evaluation of deglutition.
Performing VFS, whether as an alternative to another instrumental examinations such as videoendoscopy, is indicated in the following situations:
– difficult or incomplete clinical evaluation on account of the general conditions of the patient, for example, the presence of primitive oral reflex, such as reflex of mandibular closure;
– doubt concerning the presence of inhalation, due to possible silent aspiration, not revealed by clinical examination alone and necessarily to be excluded prior to beginning oral feeding, or, viceversa, determinant

in the choice of positioning of nasogastric tube or PEG in order to continue with feeding via the enteral route;
– need to precisely define the type and site of deglutition impairment both for therapeutic and prognostic purposes;
– planning of the rehabilitation treatment, either by means of ascertaining the efficacy of dietary modifications, such as restricted-consistency diet, and/or of the compensatory postural manoeuvres;
– follow-up of dysphagia, with the limits related to exposure to radiation involved in the examination.

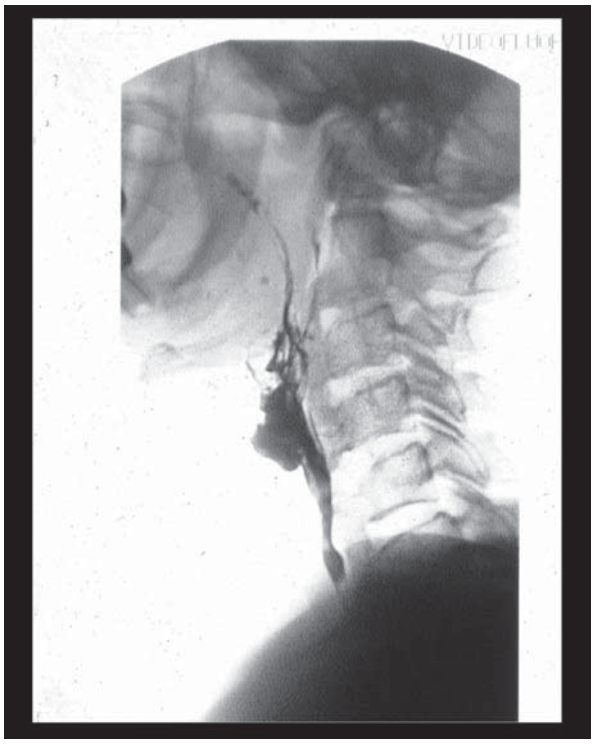

Fig. 3. Lateral view swallow during VFS, demonstrating pharyngeal residue in pyriform sinuses.

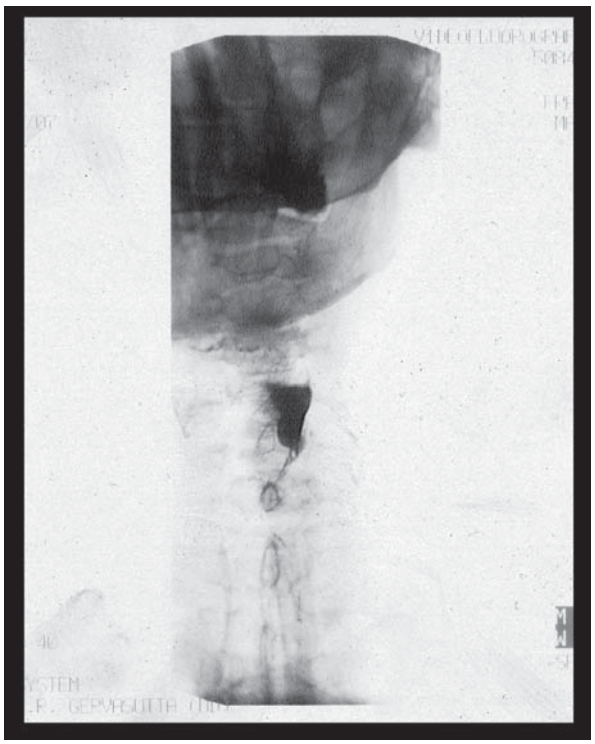

Fig. 4. Antero-posterior view of swallow during VFS, showing asymmetrical residue in left pyriform sinus.

With VFS, no changes in swallowing typical of stroke are detectable, albeit a series of changes that generally involve both the oral and pharyngeal phases of deglutition may be observed, with differences related to the location of the vascular impairment. In fact, the main impairment described is the oral phase, in stroke involving the left hemisphere, whereas the main impairment is described as the pharyngeal phase with more frequent aspiration phenomena, in stroke involving the right hemisphere, and, finally overall impairment (oral and pharyngeal) in bilateral lesions and in brainstem lesions, as typically found in Wallenberg syndrome [24]. The most frequent changes observed with VFS in the outcome of stroke are: increase in the duration of the oral phase with stasis of the bolus in the oral cavity, deficit in tongue propulsion, delay in the onset of the pharyngeal phase, with consequently possibility of predeglutitory aspiration deficit in pharyngeal propulsion, with the possibility of asymmetrical consequences due to monolateral pharyngeal paralysis and incomplete closure of the laryngeal sphincter, because of reduced hyoid and laryngeal elevation, impaired epiglottal descent and closure of the vocal cords, with consequently aspiration during swallow, stasis of the bolus in the hypopharynx (Fig. 3) and UES dysfunction, with consequently post predeglutitory aspiration. With the antero-posterior projection, it is possible to reveal, in some cases, particularly in lesions in the trunk (brainstem lesions), evident asymmetry on the side of the stasis at hypopharyngeal level (Fig. 4).
A specific negative prognostic significance has been attributed to some of these alterations regarding the increased risk of complications and the evolution of dysphagic disorders; in particular, delayed oral transit, delayed or absent swallow reflex and presence of penetration have been reported to have a negative prognostic significance [25].

Traumatic brain injury

Deglutition impairment is very frequent in severe traumatic brain injury patients, and is often associated with the prolonged disturbance of consciousness. Approximately 60-70% of patients with head trauma present varying degrees of swallowing disorders when coming out of coma [26 27]. In ~60% of the subjects, dysphagia is related to motor pattern reorganisation due to functional suspension and difficulty in beginning of the motor scheme performance, which presents as impairment mainly of the voluntary component of swallowing, i.e., preparation phase and oral phase. In other cases, a more severe dysphagia is present related, indeed, to the neurological lesion, which may involve the swallowing centre, the cortico-bulbar pathways, the cortico-spinal pathways or the peripheral motoneurone; in all these cases, impairment is often present both in the oral and the pharyngeal phase of swallowing, with changes both in the voluntary

and automatic component. The swallowing disorder in these subjects may be made more severe by prolonged endotracheal intubation and ventilator support and by the presence of tracheotomy [28]. The difficulties encountered in the evaluation of swallowing in traumatic brain injury patients are comparable to those reported in stroke patients. It is worthwhile pointing out that quite often these patients show, not only lack of collaboration, but also behavioural changes (agitation, aggressiveness) and problems related to motor reorganisation, such as postural disorders and presence of pathological reflexes (sucking, biting, repetitive tongue pumping …), which, in any case, would even make it difficult to perform VFS. Indications for performing VFS are, in essence: needed to obtain a better definition of the pathophysiological mechanism of deglutition impairment, for example, doubts related exclusively to the voluntary component of swallowing whilst maintaining or not, the automatic component, assessment of the presence and, if possible, quantification of inhalation and, the choice, on the basis of the data obtained, of the specific rehabilitation technique [29 30].

Parkinson's disease and Parkinson-like syndromes

The exact prevalence of dysphagia in these pathological situations still remains to be defined. It has been reported that approximately 50% of subjects with Parkinson's disease present swallowing disorders, even if generally of a modest degree, and of which, at times, the patient is not even aware, but is revealed exclusively by VFS. The videofluoroscopic changes in swallowing most frequently observed in Parkinson patients are: alteration in preparation of the bolus, due to repeated tongue pumping movements, increased OTT and delayed triggering of the pharyngeal phase with difficulties in starting the automatic phase of deglutition, delayed onset of laryngeal elevation, reduced epiglottic tilting and stasis in pyriform sinuses at the end of deglutition [31]. Considering that one of the most frequent causes of death, in Parkinson patients, is aspiration pneumonia, the usefulness of VFS, in all cases with suspected silent inhalation, becomes clearly evident.

Amyotrophic lateral sclerosis

Amyotrophic lateral sclerosis is the most common motor neuron disease. This is a progressive disease, generally leading to death due to impairment of respiratory function which is associated with a progressive decline in swallowing function, resulting in total dysphagia. The signs and symptoms of the disorder are: weakness, atrophy and fasciculation of the muscles involved. As far as concerns deglutition, the initial manifestation is generally dysphagia exclusive to solids with a feeling of the bolus remaining at oesophago-cervical level, due to the incomplete and delayed opening of the UES and to slowing down of oesophageal peristalsis. The main alterations detected at VFS in these subjects are: reduced oral and tongue control of the bolus, reduced tongue propulsion, delayed onset of the pharyngeal phase and of laryngeal closure associated with UES dysfunction [32]. The presence of inhalation may be found presenting either as pre-, intra- or post-deglutitory. VFS may be usefully employed when it is necessary to make a choice in the changing of diet features, such as increased viscosity and smaller bolus size, and postural manoeuvring, for instance, flexed neck for better airway closure. Furthermore, VFS evaluation of the presence of inhalation can condition the choice of when it becomes necessary to suspend oral feeling and proceed with positioning of PEG.

Multiple sclerosis

Dysphagia, in multiple sclerosis (MS), has been found to be more frequent than previously held. In fact, recent studies refer to an incidence of dysphagia in patients with MS of > 30%, reaching > 80% in the advanced forms of the disease with brainstem involvement [33 34]. Dysphagia represents one of the main causes of death in subjects with MS, and, therefore, it is clearly evident that early diagnosis and management are an absolute priority. Bearing in mind the finding that dysphagia is not uncommon also in asymptomatic subjects, has led to the opinion that an instrumental examination – represented by VFS or as an alternative to the endoscopic examination – should be carried out in all those cases in which the presence of silent aspiration is suspected [35]. By means of VFS, it is possible to diagnose the pathophysiological mechanism of aspiration, in order to be able to proceed with the most suitable steps to ensure prevention. Furthermore, UES dysfunction is frequent in MS and this can be detected only by means of VFS associated or not with manometry [36].

Aging

Numerous swallowing disorders can be detected by means of VFS in elderly subjects, for instance: slowing down of the swallowing action, with a delay in onset of the swallowing reflex (but usually not beyond the norm of 1 second), increase both in oral and pharyngeal stasis, prolonged opening phase of UES. Penetration of the bolus above the vocal cords is more frequent in the elderly than in young subjects, and is often associated with a reduction in pharyngo-laryngeal sensitivity with, consequently, a reduction in the efficacy of the cough reflex. Deterioration in physiological swallowing functions alone cannot account for the presence of oropharyngeal dysphagia, which is usually the specific result of a pathologic condition or illness that occurs more commonly in elderly persons [37 38]. One of the conditions most frequently responsible for dysphagia in the elderly is Alzheimer's disease or other dementias. In these cases, cognitive deterioration plays a determinant role in the onset of malnutrition and dehydration often observed in these subjects.

Albeit, in Alzheimer's disease, alterations in the swallowing mechanisms are often observed with VFS, most frequently involving the oral, rather than the pharyngeal phase of swallowing [39]. A minimum level of aspiration of the contrast medium has been detected in 50% of Alzheimer patients, and massive aspiration in 24% [40].

Globus pharyngeus

One possible application of VFS is in the study of deglutition in the *globus pharyngeus* (GP). This frequently observed disorder, is characterized by a sensation of a foreign body or a lump in the throat. The pathophysiology of this disorder still remains to be elucidated: the most credible hypothesis is that this is likely a manifestation of gastro-oesophageal reflux disease, albeit the involvement of neuromotor disorders cannot be excluded. In a recent publication, the results were reported of a study on a group of 23 patients with GP, evaluated by means of VFS and ambulatory pH monitoring. The latter examination showed normal results in all the patients studied, whereas VFS revealed the presence of a dysfunction in the pharyngeal phase of swallowing in 30% of the patients; in particular, in these patients, laryngeal aspiration, stasis of barium in the pyriform sinuses and poor pharyngeal elevation were revealed [41].

VFS in children

As in adults, also in children, VFS is an effective tool in demonstrating the presence of swallowing disorders and objectively assessing the adequacy of airways protection during swallowing, allowing specific modifications of feeding techniques and preventing secondary complications, such as aspiration pneumonia and chronic lung disease. The instrumental evaluation of swallowing is mandatory in those cases in which the presence of silent aspiration is suspected, and which is a particularly frequent event, especially in children with infantile cerebral paralysis. Bearing in mind the exposure to radiation to which the small patient is exposed during the course of performing VFS, any decision to submit a child to this examination should always be preceded by a scrupulous clinical assessment, based upon a careful taking of the clinical history, upon the clinical examination including evaluation of motor and sensitive function of the structures involved in swallowing and, finally upon observation of the child whilst eating a meal, in the event he/she could be fed per os. Only in those cases in which a more detailed study of swallowing is absolutely necessary, as far as concerns, in particular, the pharyngeal and oesophageal phases, or when a strong suspicion of inhalation exists, especially in the absence of a valid cough, should be an indication to perform VFS. The principal situations in which performing VFS would appear to be indicated in a child are: infantile cerebral paralysis, in which dysphagia is present in approximately 90% of patients, with a high frequency of silent aspiration; the outcomes of traumatic brain injury; other congenital or acquired neuromuscular impairments, such as cerebral tumours or juvenile dermatomyositis. VFS, instead, is not indicated in cases in which the dysphagia is due to a behavioural disorder such as "spitting out lumps", "gagging" or refusal of specific types of food, such as solids. Furthermore, VFS should not be performed in children presenting lethargy, a medically unstable situation or do not appear to present adequate collaboration to guarantee being able to successfully perform the examination [42]. The alternative to VFS, for instrumental study of swallowing in a child, is essentially fiberoptic endoscopic evaluation of swallowing (FEES): the degree of invasiveness of this examination is such that it can be used either in very small children or in an older child capable of collaborating and to accept performance of the examination. FEES, nevertheless, is a very useful investigation to define the anatomical and functional structures involved in swallowing, in particular as far as concerns the pharyngeal phase of deglutition, with sensitivity and specificity values, in the child, comparable to those with VFS, in the detection of aspiration.

The technique used in performing VFS, in the child, is, to a large extent, identical to that in the adult patient. The fact that one is faced with a small patient requires a series of careful steps aimed at favouring correct performance of the examination; first of all, the presence of the parents (or guardian), as well as of the logopaedist who already follows the child, is mandatory when performing the examination. Also important are the characteristics of the environment in which the examination is being carried out: this should, in fact, be as quiet an area as possible, maximum attention being focused on avoiding distractions and favouring the concentration of the child taking the food, whilst, at the same time, offering him/her the sensation of comfortable and familiar surroundings. The position in which the child is placed during performance of the examination is of fundamental importance: a sitting or semi-sitting position should, in fact, be adopted, recreating that normally used whilst eating food; in smaller children, in particular, there should be the possibility of slightly restraining the back and head in order, as much as possible, to avoid any movements that would lead to an increase in exposure to radiation due to the radiologist's need to follow the patient during the movement. For this purpose, special seats are available, that most commonly used being the Tumbleform chair (Sammons Preston, Bolingbrook, IL, USA), which can be easily introduced and removed from the fluoroscopic equipment and in which the child is placed in a semi-reclined position, with adequate support for head and back. Particular attention should be paid to the mode of administration and the type of substances used for the examination, in order to be able to evalutate swallowing in conditions as close as possible to those of the normal eating habits of the child. When performing VFS in a child, less attention is observed, than in an adult, as far as concerns adhering to pre-determined protocols, thus the order of presentation of different food consistencies and the modalities of administration (feeding bottle, tablespoon, a probe in order to bypass the oral cavity) are more individualised and tailor-made. In some cases, the first consistency used is that found to be most agreeable to the patient, in other cases, it may be preferable to begin with the consistency that is least likely to determine stasis, and, therefore, to negatively affect the interpretation of the exam. In other cases, if it is known that the dysphagic problems, in the child, occur only after having performed a certain number of swallows, so it may be useful to start the recording of the fluoroscopic images only after having taken a certain number of mouthfuls, i.e, the moment in which signs of dysphagia start to occur. In general, it is not necessary to interrupt the examination as soon as signs of inhalation appear, unless, of course, massive inhalation occurs, negatively affecting

the respiratory conditions; otherwise, continuation of the examination is useful in order to point out how feeding can be adjusted to reduce the risk [43]. The examination is considered finished when the logopaedist, together with the radiologist, agree that the aim of the examination has been achieved. Analysis of the examination, however, should always be determined both by the radiologist and the specialist, in order to integrate the clinical with the radiological findings.

Comparison with other techniques

The greater usefulness of the videofluoroscopic examination, compared with the bedside examination, in the diagnosis of dysphagia and in revealing the presence of inhalation has been widely demonstrated, as far as concerns swallowing disorders elicited by various causes, but primarily in dysphagia resulting from a stroke.

The sensitivity and specificity values, of the bedside examination in detecting alterations in swallowing of oropharyngeal origin, reported in the literature, considering as the gold standard VFS, vary considerably depending upon the technique used in the evaluation, timing of performance of the evaluation with respect to the pathological event and the characteristics and size of the study population; the values reported range between 40% and 80% as far as concerns sensitivity and between 59% and 91% for specificity [44-46]. From a practical viewpoint, these data confirm that if only the bedside examination of swallowing is performed this may lead to an underestimation of the presence of swallowing disorders as well as the risk of inhalation, the latter, particularly when silent aspiration is present.

Since 1988, instrumental evaluation of swallowing, by means of FEES, has appeared alongside VFS [47], and has become increasingly employed on account of the numerous advantages that the endoscopic examination offers compared to the radiological examination [48 49]. First of all, it is worthwhile stressing the accessibility, availability and low cost of the endoscopic examination, which can be performed by either a speech-language pathologist or ENT specialist, without the need to involve other professional figures, employing a manageable instrument which can easily be moved offering the possibility to perform the examination even at the patient's bedside. VFS, on the contrary, requires, above all, equipment which is not available in every health centre: the availability of VFS is influenced first of all by hospital size and secondly by the presence of departments that treat specifically patients with deglutition disorders [50]. Furthermore, VFS inevitably requires that the patient be brought to the Radiology Unit: this may represent a particularly limiting factor, especially in patients in poor general conditions or who are ventilator-dependent. Furthermore, as already pointed out, in order to perform the examination, the patient must necessarily be able, not only to maintain a sitting or semi-sitting position, but also present at least minimal collaboration, whereas with the endoscopic evaluation these requisites are not necessary, even if performing the examination in patients showing little collaboration is not always easy. VFS, which due to the exposure to the radiation involved, even if, according to some Authors, in a minimum amount [51], presents limits as far as concerns repeating the examination. Videoendoscopy, on the contrary, is a valid instrument for use in patient follow-up and in the evaluation of the outcome of treatment.

In effect, the two examinations, VFS and FEES, apart from these differences of a practical nature, offer very different information: VFS offers an indirect insight into the anatomy and functionality of the swallowing organs thanks to the opacification induced by the passing of the radio-opaque bolus across the upper digestive tract; this view is bidimensional since it is projected onto a screen, but offers the possibility to evalutate the overall dynamics of the swallowing act. FEES, on the other hand, provides direct and three-dimensional images of the upper digestive tract, with, however, the limits represented by exploration only of the pharyngeal phase of swallowing with the lack of information concerning the oral phase, and also, as far as concerns the pharyngeal phase, lack of vision during the propulsive pharyngeal phase due to the black-out caused by the turning backwards of the base of the tongue. FEES provides an excellent view of: pharyngo-laryngeal anatomy, closure of the velo-pharyngeal sphincter, motility and appearance of the vocal cords, presence of stasis of saliva in the hypopharynx, a finding which is not possible to evaluate with VFS, whilst, this, according to some Authors, is a significant index of the high risk of inhalation [52 53], and the presence of inhalation pre- or post-swallowing. Another piece of information obtained exclusively during FEES is evaluation of laryngopharyngeal sensory function, the so-called *flexible endoscopic evaluation of swallowing with sensory testing* (FEESST). The pharyngo-laryngeal sensitivity can be tested by directly stimulating, with the tip of the endoscope, the base of the tongue, the vallecule and the epiglottis or by delivering calibrated air pulses to the aryepiglottic folds in order to elicit laryngeal adductor reflex, according to the technique proposed by Aviv et al. in 1998 [54]. In actual fact, it still remains to be demonstrated how much and how the sensitivity disorder of the pharyngo-laryngeal tract is correlated with the increased risk of inhalation.

In 1988, Langmore et al. published the first report on the endoscopic study of swallowing by means of administration of coloured food items, showing marked specificity in revealing penetration and aspiration [47]. Since then, numerous reports have been published focusing on a comparison between FEES and VFS in the study of swallowing, often with controversial results. In 1997, Wu et al., in an investigation on 28 dysphagic patients, examined with FEES and VFS, reported a greater sensitivity with FEES in detecting the presence of inhalation compared to VFS [55], whereas the opposite conclusions were reported, that same year, by Kaye et al. [56]. Later, Leder et al. reported 96% agreement between FEES and VFS in revealing the presence of silent aspiration in a study on 56 patients with oropharyngeal dysphagia [57]. Analogous results have been reported, by this same Author, in the year 2000, following a study on 30 paediatric patients [58]. The only prospective study, reported, to date, is that performed by Aviv in which 126 dysphagic patients were randomly evaluated by means of FEES or VFS [59]. The outcomes of the study referred to the incidence of aspiration pneumonia and the pneumonia-free interval over

a period of 2 years: the results did not reveal any statistically significant difference between the patients studied with the two different methods.
More recently, Tabaee et al. reported the results of a retrospective study on a group of 54 dysphagic patients evaluated with both methods (FEESST and VFS), performed, within a short time, one after the other. A comparison of the results of the two examinations revealed a high percentage of disagreement in the findings emerging from the two tests regarding the presence of dysphagia and inhalation [60].
In effect, all these studies revealed the lack of a definitive demonstration of better performance of one of the two examinations with respect to the other: it is not, therefore, possible to speak of competition between these two examinations but rather of complementarity in the information that these offer, thus in theory, ideally in the study of swallowing, both should be performed.

Conclusions

For more than 20 years, i.e., since its introduction around the eighties, videofluoroscopy has been considered the gold standard in the diagnosis, choice of treatment and follow-up of swallowing disorders, in general, but of dysphagia of neurological origin, in particular. Over the years, however, the role of videofluoroscopy has, in part, been challenged particularly on account of the introduction of endoscopy in the diagnosis of dysphagia. This latter examination offers, in fact, numerous advantages, above all in terms of possibility of immediate performance, costs and repeatability compared to VFS, even if also this procedure presents numerous limits related to the type of information supplied. At present, it still remains to be decided which is the ideal instrumental examination for the study of swallowing and this is easily explained if we bear in mind that an examination may be considered ideal according to the type of information that we hope to achieve from it. But the swallowing disorders to be studied vary considerably, from oro-pharyngeal dysphagia, in a patient with evidence of severe traumatic brain injury, to that of a totally oral nature in a patient having undergone demolitive surgery on the oral cavity, from progressive dysphagia in degenerative neurological disorders to situations certainly less dramatic, such as patients presenting pharyngeal globus or chronic dysphagias of an unknown nature, but in which diagnosis can often be extremely difficult. Furthermore, a patient with swallowing disorders presents, in any case, a vast number of subjective variables, related to age, general conditions, and above all the presence of associated disorders, such as cognitive impairment, with reduced collaborative capacity, fluctuating alertness level, limitations in maintaining erect posture, respiratory disorders, etc. Finally when selecting an instrumental examination for the study of swallowing, as much will depend upon whether we are dealing with: a hospitalised patient or outpatient, whether or not the patient can be transported elsewhere, the availability of the necessary instrumentation in the health centre in which the specialist is found, and, not to be overlooked, the costs involved in performing all the different examinations.
Results of studies reported, so far, have not clearly demonstrated significant differences regarding maximum diagnostic efficacy of one exam with respect to another, but it is worthwhile pointing out that most of the studies were of a retrospective nature and it is, therefore, necessary to have the opportunity to draw conclusions from prospective studies which probably use other endpoints besides the incidence of pneumonia *ab injestis*, such as, for instance, the quality of life and the general clinical conditions of the subject.
In conclusion, at present, the role of VFS continues to be essential in the diagnosis and planning of rehabilitation treatment for dysphagia, particularly in that of neurological origin, even if performance of this examination should always be preceded by a careful and overall clinical evaluation of the patient on the part of the specialist, who will then decide upon the need to perform the examination on the basis of the findings obtained.

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