A Method to Objectively Assess Swallow Function in Adults With Suspected Aspiration

TAHER I. OMARI,[*,‡] EDDY DEJAEGER,[§] DIRK VAN BECKEVOORT,[‖] ANN GOELEVEN,[¶,#] GEOFFREY P. DAVIDSON,[*,‡] JOHN DENT,[**] JAN TACK[‡‡], and NATHALIE ROMMEL[#,‡‡]

[*]Gastroenterology Unit, Child, Youth & Women's Health Service, North Adelaide, South Australia, Australia; [‡]School of Paediatrics and Reproductive Health, University of Adelaide, Adelaide, South Australia, Australia; [§]Geriatric Medicine, University Hospital Leuven, Leuven, Belgium; [‖]Radiology, University Hospital Leuven, Leuven, Belgium; [¶]ENT, Head and Neck Surgery, MUCLA, University Hospital Leuven, Leuven, Belgium; [#]Department of Neurosciences, ExpORL, University of Leuven, Leuven, Belgium; [**]Department of Gastroenterology and Hepatology, Royal Adelaide Hospital, Adelaide, SA, Australia; [‡‡]Neurogastroenterology Clinic, University Hospital Leuven, Leuven, Belgium

BACKGROUND & AIMS: Pharyngeal manometry and impedance provide information on swallow function. We developed a new analysis approach for assessment of aspiration risk. **METHODS:** We studied 20 patients (30–95 years old) with suspected aspiration who were referred for videofluoroscopy, along with controls (ages 24–47 years). The pharyngeal phase of liquid bolus swallowing was recorded with manometry and impedance. Data from the first swallow of a bolus and subsequent clearing swallows were analyzed. We scored fluoroscopic evidence of aspiration and investigated a range of computationally derived functional variables. Of these, 4 stood out as having high diagnostic value: peak pressure (PeakP), pressure at nadir impedance (PNadImp), time from nadir impedance to peak pressure (TNadImp–PeakP), and the interval of impedance drop in the distal pharynx (flow interval). **RESULTS:** During 54 liquid, first swallows and 40 clearing swallows, aspiration was observed in 35 (13 patients). Compared to those of controls, patient swallows were characterized by a lower PeakP, higher PNadImp, longer flow interval, and shorter TNadImp–PeakP. A Swallow Risk Index (SRI), designed to identify dysfunctions associated with aspiration, was developed from iterative evaluations of variables. The average first swallow SRI correlated with the average aspiration score ($r = 0.846$, $P < .00001$ for Spearman Rank Correlation). An average SRI of 15, when used as a cutoff, predicted aspiration during fluoroscopy for this cohort ($\kappa = 1.0$). **CONCLUSIONS: Pressure-flow variables derived from automated analysis of combined manometric/impedance measurements provide valuable diagnostic information. When combined into an SRI, these measurements are a robust predictor of aspiration.**

Keywords: Manometry Impedance; Esophagus; Clinical Trial; Swallowing Defects.

Manometry has been used to assess pharyngoesophageal motor function in a variety of pathologies that cause pharyngeal weakness or impaired upper esophageal sphincter (UES) relaxation. Such disorders lead to ineffective pharyngeal bolus clearance and/or aspiration. The manometric technologies used for this assessment have evolved from single point sensors, to movement-tolerant sleeve sensors and, most recently, multiple closely spaced solid-state point sensors, that is, high resolution manometry. These manometric methods have been used to describe the alterations in pressure patterns in relation to well-recognized causes of aspiration. These include age-related changes, neurodegenerative disease, postsurgical dysfunctions, and abnormalities of UES opening due to various factors.[1–8]

Use of manometry for assessment of aspiration risk has been very limited in routine clinical practice. This is because manometric criteria alone have not been shown to accurately assess risk of aspiration and/or post-swallow bolus residue (henceforth called *residue*). Consequently, swallow assessment with videofluoroscopy (henceforth called *fluoroscopy*) is often considered necessary, irrespective of whether manometry is performed.

Intraluminal impedance measurement has emerged in recent years as a technique that can be used to detect failed esophageal bolus transport and, when combined with esophageal manometry, several patterns of ineffective esophageal body peristalsis. By contrast, the application of impedance measurement to the pharynx has proven extremely challenging. Pharyngeal swallow events occur over a much shorter time span than esophageal peristalsis and several factors cause large variations of the baseline level of impedance, such as variable mucosal contact, residue, and secretions. These factors cause impedance signals to be much more noisy than in the

Abbreviations used in this paper: IQR, interquartile range; msu, median standardized units; NadImp, nadir impedance; NadUESP, UES nadir relaxation pressure; OR, odds ratio; PNadImp, pressure at nadir impedance; ROI, region of interest; SRI, Swallow Risk Index; TNadImp-PeakP, time from nadir impedance to peak pressure; UES, upper esophageal sphincter; UES-IBP, UES median intrabolus pressure; UES-RI, UES relaxation interval.

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esophagus, so that attempts to optimize criteria that identify aberrant bolus flow events and residue have only been partially successful.[9–11]

Observation of pharyngoesophageal bolus transit using fluoroscopy is considered the gold standard for evaluation of direct aspiration; however, fluoroscopy requires exposure to ionizing radiation and the information provided is mainly qualitative, although it is possible to derive some numerical measures; such as the timing of opening or closing of the glossopharyngeal junction, velopharyngeal junction, laryngeal vestibule, and UES, which provides information on the function of the mechanisms of airway protection and can be used to assess aspiration risk.[12,13] Quantitative fluoroscopy measures such as these are not derived routinely, presumably because they are considered too time-consuming and cumbersome, although possible.

In typical clinical scenarios, patients are not usually referred for fluoroscopy until they have deteriorated clinically with major symptoms. Fluoroscopy is, therefore, used most frequently as an assessment method for symptomatic patients rather than as a screening test for patients at risk but are otherwise doing well. Such patients can benefit from repeated screening over time to catch aspiration before symptoms develop. It is, however, difficult to justify repeated screening using fluoroscopy because of the radiation exposure and clear evidence that fluoroscopy is a relatively poor predictor of development of aspiration pneumonia.[14,15] This is probably due to the fact that susceptibility to aspiration pneumonia is multifactorial.[16] Nevertheless, if a sensitive and specific approach were available that did not require radiology and was relatively simple to perform, then such a test would have a potential role in identifying patients with deglutitive aspiration at a time when aspiration-associated complications might be prevented by intervention.

The aim of this study was to develop a new approach for the objective assessment of pharyngeal mechanical function relevant to aspiration using high-resolution intraluminal manometry combined with impedance measurement (hence forth call *manometry and impedance*). These data were explored for criteria that would enable recognition of individuals at high risk for clinically significant aspiration, without performance of fluoroscopy.

Materials and Methods

Subjects

Twenty patients (13 male; mean, 68.2 years; range, 30–95 years) were studied and underwent simultaneous manometry and impedance and fluoroscopy. All were referred to the swallowing clinic for a videomanometric study of the pharynx and esophagus because of clinical suspicion of deglutitive aspiration due to a deglutition disorder. Underlying diseases/conditions were identified through a review of medical records. The majority of patients had a history of neurological disease or neurosurgery (Figure 1). For comparison, 10 healthy adult subjects were recruited who had no swallowing difficulties or other symptoms suggestive of a motility disorder (5 male; mean, 36.6 years; range, 24–47 years). The study protocol was approved by the Research Ethics Committee, University Hospitals Leuven, Belgium.

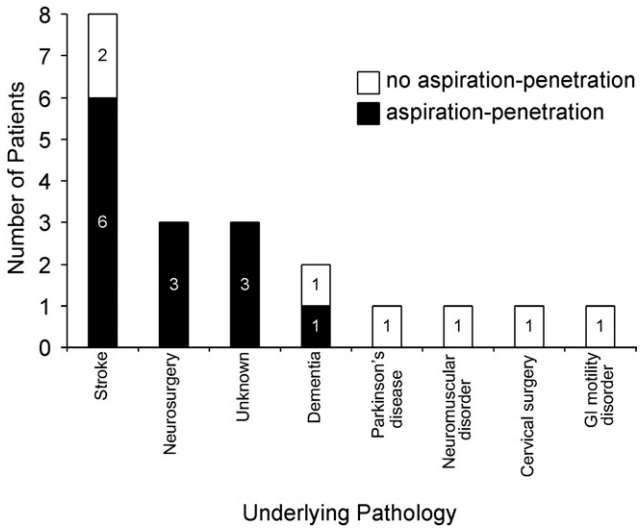

Figure 1. A summary of the patient cohort according underlying medical pathology and presence of aspiration-penetration as detected on videofluoroscopy.

Measurement Technique

Studies were performed in the Radiology Department, University Hospitals Leuven with a 3.2-mm diameter solid state manometric and impedance catheter incorporating twenty-five 1-cm–spaced pressure sensors and 12 adjoining impedance segments, each 2 cm (Unisensor USA Inc, Portsmouth, NH). Subjects were intubated after topical anesthesia (lignocaine spray) and the catheter was positioned with sensors straddling the entire pharyngoesophageal segment (velopharynx to proximal esophagus). Pressure and impedance data were acquired at 20 Hz (Solar GI Acquisition System, MMS, The Netherlands) with the patient sitting upright. As per routine clinical fluoroscopy, test boluses of 5 and/or 10 mL liquid were administered orally via syringe. The boluses given were standardized across all the patients and controls studied. A standard liquid contrast material (MicropaqueH) was given as liquid bolus. A low osmotic hydrosoluble iodium compound (UltravistH) was used when aspiration was suspected. The viscosity of the administered boluses was determined by a Rheomat 115 Viscometer. The Bingham viscosity of the liquid Barium (MicropaqueH) was 0.22PA s. All bolus stock contained 1% NaCl to enhance conductivity.

Video-loops of the fluoroscopic images of swallows were simultaneously acquired at 25 frames/s. The first swallow that followed bolus administration to the mouth