ORIGINAL ARTICLE

FEES-based assessment of pharyngeal hypesthesia—Proposal and validation of a new test procedure

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Abstract

Background: Intact pharyngeal sensation is essential for a physiological swallowing process, and conversely, pharyngeal hypesthesia can cause dysphagia. This study introduces and validates a diagnostic test to quantify pharyngeal hypesthesia.

Methods: A total of 20 healthy volunteers were included in a prospective study. Flexible endoscopic evaluation of swallowing (FEES) and a sensory test were performed both before and after pharyngeal local anesthesia. To test pharyngeal sensation, a small tube was positioned transnasally in the upper third of the oropharynx with contact to the lateral pharyngeal wall. Increasing volumes of blue-dyed water were injected through the tube, and the latency of swallowing response (LSR) was determined by two independent raters from the endoscopic video recording. Three trials were performed for each administered volume starting with 0.1 mL and increased by 0.1 mL up to 0.5 mL.

Key Results: The average LSR without anesthesia was 2.24 ± 0.80 s at 0.1 mL, 1.79 ± 0.84 s at 0.2 mL, 1.29 ± 0.62 s at 0.3 mL, 1.17 ± 0.41 s at 0.4 mL, and 1.19 ± 0.52 s at 0.5 mL. With anesthesia applied, the average LSR was 2.65 ± 0.62 s at 0.1 mL, 2.64 ± 0.49 s at 0.2 mL, 2.44 ± 0.66 s at 0.3 mL, 2.10 ± 0.81 s at 0.4 mL, and 2.18 ± 0.85 s at 0.5 mL. LSR was significantly longer following anesthesia at 0.2 mL (t = −3.82; P = .001), 0.3 mL (t = −4.65; P < .000), 0.4 mL (t = −5.77; P < .000), and 0.5 mL (t = −3.49; P = .005).

Conclusion and Inferences: Pharyngeal hypesthesia can be quantified with sensory testing using LSR. Suitable volumes to distinguish between normal and impaired pharyngeal sensation are 0.2 mL, 0.3 mL, 0.4 mL and 0.5 mL. Experimentally induced pharyngeal anesthesia represents a valid model of sensory dysphagia.
1 | INTRODUCTION

Swallowing disorders frequently occur in neurological patients. In addition to malnutrition and dehydration, they are associated with serious complications such as aspiration pneumonia and an increased mortality.\(^1\) Intact pharyngeal sensation is crucial for a physiological swallowing process, and conversely, pharyngeal hypesthesia can cause dysphagia.\(^2,3\) Sensory information of the oropharynx such as taste, pressure, and temperature is transmitted via sensory fibers of the trigeminal, facial, glossopharyngeal, and vagal nerves to the central nervous system.\(^4\) Here, the Central pattern generator (CPG) located in the brainstem coordinates the swallowing muscles using the sensory input from the cranial nerves.\(^5\) Cortical areas are associated with the volitional initiation and modulation of swallowing.\(^9\) At the cortical level, reduced sensory input causes a decreased somatosensory swallowing activation which also leads to an impaired motor coordination.\(^15\) Pharyngeal sensation therefore provides key feedback for swallowing coordination at both the level of the brainstem and the cortex.

Consistent with this model, the dissection of the laryngeal sensory nerves in animal models was associated with swallowing dysfunction and silent aspiration.\(^18\) Similarly, anesthesia of the larynx in healthy humans was noted to be accompanied by transient dysphagia.\(^19\) In addition, in a mixed patient group, decreased laryngeal sensation was associated with the severity of pharyngeal residue and impaired residue clearing.\(^20\) Pharyngeal hypesthesia can be caused both centrally, for example, by damage to somatosensory cortical areas, and peripherally, for example, by injury of the pharyngeal mucosa. Therefore, there is a huge spectrum of different diseases in which impaired sensory feedback or its central processing contributes to dysphagia. In post stroke dysphagia, laryngeal hypesthesia is associated with altered motor activity and aspiration.\(^21\) In Parkinson's disease sensory, pharyngeal nerves are directly affected by the Lewy pathology, which is associated with dysphagia.\(^23\) In geriatric patients with dysphagia, age-related reduced pharyngeal sensation is an important contributing factor.\(^25\) In intensive care, intubation-induced mucosal damage often leads to laryngeal sensory deficits and can result in post-extubation dysphagia.\(^26\) In patients with chronic obstructive pulmonary disease (COPD), pharyngeal hypesthesia related to dysphagia has been reported, which in turn exacerbates COPD after aspiration and consecutive broncho-pneumonia. Impaired pharyngeal sensation in COPD is presumably caused by gastroesophageal reflux and damage to the mucosa.\(^27\)

Pharyngeal hypesthesia thus plays an important role in the pathophysiology of neurogenic dysphagia. The aim of this study was therefore to develop and validate a method to assess and quantify pharyngeal hypesthesia. For this purpose, a sensory test was designed in which latency of swallowing was determined as a reaction to pharyngeal liquid application. The test was combined with flexible endoscopic evaluation of swallowing (FEES), which is one of the most common and well-tolerated methods to objectively assess dysphagia.\(^28\)

2 | MATERIALS AND METHODS

2.1 | Study cohort

A total of 20 healthy volunteers without pre-existing neurological conditions or swallowing difficulties were included in the study. Informed consent was obtained from each subject after the study was explained according to the declaration of Helsinki. The local ethics committee has approved the nature of the study.

2.2 | Study protocol

FEES and FEES-based sensory testing were performed before and after anesthesia of the pharynx. The examination was recorded and stored on video for later evaluation. The different examination steps are described in the following.

2.3 | Pharyngeal anesthesia

The pharyngeal mucosa was anesthetized using 12 puffs of 2% lidocaine spray. Subjects were asked to swallow every second spray to achieve adequate anesthesia. If after 30 seconds, soft touches at the base of the tongue with a swab could still be noticed, 3 additional puffs of lidocaine were applied. The detailed procedure of pharyngeal anesthesia is described elsewhere.\(^15\)

KEYWORDS
dysphagia, FEES, FEESST, laryngeal adductor reflex, pharyngeal hypesthesia

**Key Points**

- Intact sensation is essential for a physiological swallowing process and conversely pharyngeal hypesthesia can cause dysphagia.
- This study introduces and validates an endoscopic test procedure in which pharyngeal hypesthesia is quantified by the latency of swallowing in response to pharyngeal application of different liquid volumes.
- The detection and quantification of pharyngeal hypesthesia as a cause of dysphagia are crucial for targeted dysphagia therapy and for scientific purpose.
2.4 | Swallowing assessment

Flexible endoscopic evaluation of swallowing was performed according to a standardized protocol with testing of three different food consistencies in the following order: three trials of 8 mL of green jelly (semisolid), three trials of 5 mL blue-dyed liquid, and three trials of white bread (solid) with a size of approximately 3 × 3 × 1 cm. Swallowing was rated using a score which evaluates three parameters of swallowing function: (a) premature bolus spillage, (b) penetration and aspiration, and (c) residue in the pharynx caused by insufficient bolus clearance. Each parameter is rated on a scale from 0 (normal) to 4 (severe impairment) for each trial and each food consistency, contributing to an overall cumulative score ranging from 0 to 108. The score is described in detail elsewhere and has recently been validated.

2.5 | Sensory test

An eight Charrière infant feeding tube (external diameter of 2.67 mm, internal diameter of approximately 1.5 mm) was placed transnasally under FEES-control. The tube was placed in the upper third of the oropharynx with the tip of the tube in contact with the lateral wall of the oropharynx. Thereafter, different volumes of blue-dyed water were applied via the tube and the latency of the swallow response (LSR) was measured. LSR was defined as time period from the beginning of water injection to the beginning of the white-out in FEES. All videos were rated off-line in randomized order with the rater kept blinded to the subject’s condition (ie, anesthesia or no anesthesia). Three trials were performed for each administered volume starting with 0.1 mL. The volume was increased in 0.1 mL steps up to 0.5 mL. If subjects showed no reaction to the application after 3 seconds, they were asked to swallow. This time was chosen in accordance with Teramoto et al who defined a missing swallowing reflex as lack of response within 3 seconds. For the final determination of LSR, the average measured time of two independent raters for each trial was calculated. In cases of a missing swallowing reflex, LSR was set to 3 seconds. The positioning of the tube at the lateral pharyngeal wall is shown schematically in Figure 1. Figure 2 shows the view as it appears in FEES.

2.6 | Inter-rater and retest reliability

LSR was determined independently by two raters. In five randomly selected subjects, LSR was re-evaluated 3 weeks after the first rating.

2.7 | Statistical analysis

The data are presented as frequencies for categorical variables and as means ± standard deviation for metric variables. The swallowing score and LSR before and after anesthesia were compared using the t test for dependent variables. In the case of significant results, the effect size Cohen’s d was calculated as following: 
\[ d = \frac{\text{mean}}{\text{standard deviation}} \]
A repeated measures ANOVA with a Greenhouse-Geisser correction was used to test whether LSR differed between the tested volumes in both conditions with and without anesthesia. A post hoc test using the Bonferroni correction was used to compare the different volumes. The intraclass correlation coefficient (ICC) was used as a measure for inter-rater and retest reliability with a two-way mixed-effect model based on absolute agreement. Mean estimations along with 95% confidence intervals (CI) were reported for each ICC. Interpretation according to Koo et al was as follows: <0.50, poor; between 0.50 and 0.75, fair, between 0.75 and 0.90 good; above 0.90, excellent.

3 | RESULTS

3.1 | Demographics

Eight subjects were male (40%) and 12 were female (60%), the average age was 28.2 ± 5.7 years.
3.2 | Swallowing assessment

The mean swallowing score before anesthesia was 3.58 ± 3.32 and increased significantly to 6.84 ± 5.45 in the anesthesia condition.

3.3 | Inter-rater and retest reliability

The average ICC for inter-rater reliability of the sensory test was 0.99 (95% CI 0.97-0.98). The average ICC for retest reliability was 0.99 (95% CI 0.99-0.99).

3.4 | Sensory test

The average LSR, the number of cases in which LSR was set to 3 seconds due to a missing swallowing reflex and the p-value of the comparison of the two conditions with and without anesthesia are shown in Table 1. The comparison of the LSR before and after anesthesia revealed a significantly longer LSR following anesthesia at 0.2 mL [t(18) = -3.82; P = .001; d = 0.88], 0.3 mL [t(15) = -4.65; P < .000; d = 1.16], 0.4 mL [t(12) = -5.77; P < .000; d = 1.60], and 0.5 mL [t(11) = -3.49; P = .005; d = 1.01]. At 0.1 mL the difference was not significant [t(17) = -1.90; P = .074].

The average LSR decreased with increasing volumes in both conditions without anesthesia [F(2.94,44.08)=23.41, P < .000] and with anesthesia [F(2.91,42.17)=7.86, P < .000]. The post hoc test revealed that in subjects without anesthesia, LSR decreased significantly from 0.1 to 0.2 mL (P = .028) and from 0.2 to 0.3 mL (P = .007). It then reached a minimum value without further decrease. In the anesthesia condition, the LSR decreased only with larger volumes and was significantly different between 0.2 mL and 0.4 mL (P = .04) and then also reached a minimum value without further decrease. The average LSRs depending on the volume are illustrated in Figure 3.

4 | DISCUSSION

This proof-of-concept study showed that artificially induced pharyngeal hypesthesia could be assessed precisely with a FEES-guided sensory test using LSR upon pharyngeal injection of increasing volumes of water. Inter-rater and retest reliability of this test can be considered as excellent.32 With this procedure, pharyngeal sensation is quantified according to the following two parameters: first the LSR and second the extent of stimulation, that is, the volume of water, needed to induce this response. Anesthesia and non-anesthesia condition were separated best with 0.2, 0.3, 0.4, and 0.5 mL.

Our results indicate that there is a ceiling effect of the LSR. In the non-anesthesia condition, LSR reached its minimum at 0.3 mL without further significant decrease. In the anesthesia condition, this was observed at 0.4 mL. The smallest volume to achieve the shortest LSR can be considered as measure for the sensory threshold. For this reason, in future applications, sensory testing should start with 0.2 mL and the volume should be further increased, ideally at least until there is no further decrease in LSR. In addition, the shortest LSR seems to be affected by pharyngeal hypesthesia and was significantly higher compared with physiological conditions. Therefore, this parameter may also be relevant in the assessment of pharyngeal hypesthesia and should be investigated in future studies.

As second main finding, our study is in keeping with previous trials suggesting that dysphagia may be critically aggravated or even mainly caused by sensory disruption. Sulica et al19 were able to show that bilateral superior laryngeal nerve block in healthy volunteers resulted in premature spillage, pharyngeal residue, penetration, and aspiration. In the present study, global swallowing impairment was rated with a previously established score evaluating and integrating parameters of swallowing safety and efficacy. While most subjects showed unimpaired deglutition at baseline, their swallowing performance slightly but significantly worsened with anesthesia applied.

### Table 1

| Volume | No anesthesia | With anesthesia |
|--------|---------------|-----------------|
|        | mean LSR ± SD | mean LSR ± SD  |
| 0.1 mL | 2.24 ± 0.80   | 2.65 ± 0.62     |
| 0.2 mL | 1.79 ± 0.84   | 2.64 ± 0.49     |
| 0.3 mL | 1.29 ± 0.62   | 2.44 ± 0.65     |
| 0.4 mL | 1.17 ± 0.41   | 2.10 ± 0.80     |
| 0.5 mL | 1.19 ± 0.52   | 2.18 ± 0.85     |

*Represents a statistically significant difference
Therefore, our study supports the use of this experimental approach as a suitable model for dysphagia caused by hypesthesia in future studies.

There are few studies that have developed methods for measuring pharyngeal hypesthesia using (semi-)quantitative read-outs. Our FEES-based approach to assess pharyngeal sensation heavily builds on the previously established swallowing provocation test (SPT) by Teramoto et al. The SPT was developed as a two-step dysphagia screening tool in which 0.4 mL of water are applied in a first step and 2.0 mL in a second step via a transnasal catheter. The onset of swallowing is determined by visual inspection and the time from the start of water injection to the characteristic laryngeal movement is measured. In stroke patients, it was shown that sensitivity and specificity of the SPT is superior to a simple water swallow test in detecting aspiration. A further study showed that 0.4 mL had a better sensitivity with the same specificity compared with the second step using 2.0 mL. Thus, 0.4 mL, in line with the results of our study, was considered to be superior in differentiating between a physiological and pathological swallowing response.

Tejima et al used a set-up comparable to the present study and applied the SPT combined with FEES in a geriatric patient cohort. They were able to show that better oral intake and improvement of dysphagia during follow-up were associated with shorter swallowing latencies. The average LSR of 7.43 seconds at 0.4 mL in their study was considerably higher than in our study, despite a similar test procedure. This indicates, that LSR may indeed be a good measure to differentiate clinical conditions and patient cohorts. In addition, the upper limit of 3 seconds might be too short to define a missing swallowing reflex in patients with severe sensory impairment and should possibly be extended in future studies. However, during prolonged periods, it is difficult to assess whether a swallow occurred in response to the stimulus or spontaneously unrelated to the previous sensory stimulation. According to our results without anesthesia, a maximum LSR of 3 seconds under physiological conditions at a volume above 0.3 mL hardly seems to be exceeded.

The only test in literature so far that is intended to precisely quantify pharyngeal sensation is the air pulse method (Flexible Endoscopic Evaluation of Swallowing with Sensory Testing (FEESST)). Here, an air pulse is applied to the anterior pharyngeal wall through an additional channel of the endoscope. The pressure of the air pulse can be varied and thus, a threshold value is determined at which the laryngeal adductor reflex is triggered. The clinical relevance of the air pulse method has been discussed controversially, and conflicting results have been published. In one study, the absence of the laryngeal adductor reflex was associated with aspiration and penetration in a mixed collective of dysphagic patients. In another study with patients after radiotherapy of head and neck tumors, this association could not be confirmed. One explanation for the discrepant findings may be a low inter-observer agreement, which is likely due to the difficulty in establishing a standard distance to the pharynx from the tip of the endoscope. In our study, we tried to avoid a similar problem by using quantifiable liquid volumes. In addition, the approach suggested in this paper is not critically dependent on the exact position of the catheter used for water injection as it is directly attached to the pharyngeal wall.

A very straight-forward method to assess sensory function during FEES is the so-called "touch-technique". This approach involves touching the epiglottis or the aryepiglottic folds with the tip of the endoscope during transnasal endoscopy. In response to this stimulus patient reactions, in particular laryngeal adductor response, eye blinking, tearing, throat clearing, swallowing, and coughing are observed. In a study comparing the air pulse method with the touch method, impaired pharyngeal sensation was found more frequently with the air pulse method, but did not correlate with the risk of penetration and aspiration. Sensory deficits revealed using the touch method were associated with an increased risk of aspiration and thus can be considered as clinically relevant. However, the results of the touch-technique are essentially binary, that is, sensory function is classified as normal or abnormal. A further quantification of pharyngeal hypesthesia is therefore limited. In addition, the pressure which is applied with the tip of the endoscope is variable, which may result in diagnostic inaccuracy.

There are several limitations to our study that need to be addressed. As the study was conducted in healthy young subjects, conclusions on patients should be drawn cautiously and further studies in different patient cohorts are critically needed. Sensory function is evaluated indirectly by triggering a motor response. This procedure does not differentiate between disturbance in the afferent (sensory) and efferent (motoric) pathway. LSR was set to 3 seconds if swallowing reflex was missing within this time period. This might have biased the results that is, differences between the two conditions (no anesthesia vs with anesthesia) might appear less severe than they actually are. When comparing the results with other studies on swallowing latency, it must be considered that catheters with different diameters were used. This could have led to varying pressures and thus have influenced the sensory response regardless of the volume applied. The sample size of 20 does not allow correlation analyses with parameters of swallowing impairments such as aspiration and penetration. Retest reliability was only determined on the bases of five follow-up ratings. Although video rating was done off-line and blinded to the subject’s condition, during the examination subjects and examiners were not blinded which might have biased their test performance. Interindividual differences in the positioning of the tube could have led to variability in LSR. Further, we did not independently assess the effect of pharyngeal anesthesia which might have led to interindividual variability in LSR depending on the extent of anesthesia.

In conclusion, this study suggests that assessing pharyngeal sensory function with successively increasing volumes of water injection is technically feasible, features a high inter-rater and retest reliability and differentiates impaired from unimpaired sensory function. Further studies in different patient cohorts are needed to explore the clinical impact of this technique.

**CONFLICT OF INTEREST**

The authors declare no conflict of interest.
AUTHOR CONTRIBUTIONS

BL, PM, MO, IC, and TM performed the research. RD, TW, SS, and TM designed the research study. BL and MO analyzed the data. BL and RD wrote the paper. PM, MO, IC, TM, SS, TW, and JS edited the paper.

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