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# Aspiration Risk Screening With Tongue Pressure Measurement in Acute Stroke: A Diagnostic Accuracy Study Using STARD Guidelines

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## Abstract

**Introduction:** Dysphagia can affect more than 50% of stroke patients in the acute phase. Aspiration pneumonia is a serious complication that can be prevented with dysphagia screening and assessment. Measurement of tongue elevation pressure is suggested to be a useful tool in aspiration risk screening.

**Objective:** This study aimed to assess the diagnostic accuracy of maximum anterior tongue elevation strength ($P_{max}$) in acute stroke care.

**Method:** In this prospective study, data were collected in a neurology department (stroke center) where patients formed a consecutive case series. The sample consisted of thirty stroke patients who failed an initial dysphagia screening. Patients underwent anterior tongue elevation strength measurement (index test) during bedside dysphagia assessment by a speech-language pathologist and flexible endoscopic evaluation of swallowing (reference test) by an otorhinolaryngologist on the same day. Outcome variables (index values in kPa, reference values interpreted on the penetration-aspiration scale) were used for estimating measures of diagnostic accuracy in aspiration risk screening.

**Results:** Ten patients aspirated on instrumental evaluation. At the cut-off point of $\leq 34$ kPa the analysis showed 90% sensitivity, 35% specificity, 41% positive predictive value, and 88% negative predictive value. The area under the curve (AUC) for $P_{max}$ was AUC = 0.700 (95% CI [0.500–0.900]).

**Conclusion:** Although individuals with low anterior tongue elevation strength tend to have a higher risk of aspiration, this variable alone is not capable of screening aspiration in acute stroke. In combination with a thorough noninstrumental bedside examination, it might have the potential to reduce the number of false positive cases. Further studies in this area would be worthwhile.

## Keywords

acute stroke, dysphagia screening, bedside assessment, swallowing diagnostics, tongue pressure

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## Introduction

Dysphagia can affect more than 50% of stroke patients in the acute phase (Banda et al., 2022). Aspiration pneumonia is one of its most serious complications (Martino et al., 2005) that can be reduced (Hinchey et al., 2005) thus dysphagia screening and assessment have become part of evidence-based treatment (Fedder, 2017). For patients at risk of aspiration, an instrumental assessment should be conducted. In the case of stroke, where mobility or even sitting balance is often limited, Flexible Endoscopic Evaluation of Swallowing (FEES; Nacci et al., 2008) might be the most optimal

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choice which can be done at the bedside although in many cases the Video Fluoroscopic Swallow Study (East et al., 2014) may be more informative (Swan et al., 2019). Where the availability of instrumental assessment is limited the request for such examination must be well-founded.

## Review of Literature

Standardized screeners are usually very sensitive tests (Edmiaston et al., 2014; Martino et al., 2009; Trapl et al., 2007) filtering all at risk but creating numerous false positives that might be reduced with a thorough noninstrumental assessment (Lindroos & Johansson, 2022; Simpelaere et al., 2023). However, there is no agreement on what type of examinations it should consist of. According to Speyer et al. (2022), there is no comprehensive overview of clinical assessments yet although there are four key categories according to the literature. The first is "cognition and communication" because the patient's active participation (understanding and following instructions, carrying out exercises) is a prerequisite of successful dysphagia therapy. Secondly, "oral, laryngeal, and pharyngeal anatomy, physiology, and function" forms the basis of the diagnostic process, addressing the key elements of a dysphagia therapy plan. Thirdly, "oral intake and nutritional status" determines the targeted values for clinical nutrition according to the patient's physiological needs. And last but not least "intervention trials" include compensatory and therapeutic techniques.

The examination of the oral, laryngeal, and pharyngeal functions might be challenging because they are mostly based on the examiner's proficient observations and subjective judgments, however nowadays some of the clinical features can be measured by objective techniques which are quite helpful. For example the facial range of motion with the computerized Sunnybrook Facial Grading System (Jirawatnotai et al., 2021), or voice quality with the acoustic parameters of the "wet voice" (Murugappan et al., 2010).

The daily use of these kinds of measurements might be time-consuming and circumstantial but for more precise monitoring of swallowing, some type of additional, noninvasive measurements are clinically relevant as part of the "noninstrumental" assessment. One such important, precisely measurable parameter in deglutition is pressure, and since the primary driving forces for bolus propulsion are the tongue-to-palate pressures (Steele & Cichero, 2014) oropharyngeal dysphagia has been associated with tongue strength (Hirota et al., 2010; Hori et al., 2005; Shaker et al., 1988). Measurement of maximum anterior tongue elevation strength is now widely available through standardized, commercially available devices (*IOPI Medical LLC*, 2023; Yoshikawa et al., 2021), however in dysphagia management it is mainly used in rehabilitation. Butler et al. (2011) found that in healthy older adults' tongue strength correlates with penetration and aspiration. It has been suggested that reduced maximum anterior tongue elevation strength in "adults at risk for aspiration" should be referred for further instrumental assessment. Nakamori et al. (2016) investigated acute stroke patients and found that patients with pneumonia had significantly lower tongue strength than those without and concluded that it is a sensitive indicator for predicting pneumonia occurrence. Oliveira et al. (2017) found that stroke patients with dysphagia had lower tongue strength than those without. Beyond that, Lee and Choi (2020) claim that tongue strength has similar predictive abilities to bedside tests screening aspiration and penetration in stroke patients and even call it a new screening test to reduce the risk of pneumonia. From this point of view, the maximum anterior tongue elevation strength measurement can be an effective additional tool for neurogenic dysphagia evaluation, especially in poststroke patients in clinical application.

### *Objective*

The primary aim of this prospective study was to assess the diagnostic accuracy of the anterior tongue elevation strength measurement for aspiration risk in acute stroke using the Standards for the Reporting of Diagnostic Accuracy Studies guidelines (Bossuyt et al., 2015). Earlier research used mixed samples (Keskool et al., 2018) thus we strived for coherence in a single stroke center. According to the researchers' current knowledge this measurement was not tested on an acute stroke sample which might be the novelty of this study and provides some additional information to the existing literature.

## Method

### *Design*

This is a single-centered quantitative observational validation study. Dysphagia management is performed in a team (neurologist, otorhinolaryngologist, nurse, dietitian, speech-language pathologist [SLP]). Dysphagia is screened after admission of every acute stroke patient. The positive cases are referred to the SLP for further noninstrumental assessment. Based on the assessment the need for instrumental evaluation is discussed and the patient is referred to the otorhinolaryngologist. The improvement of the dysphagia management protocol by measurements of tongue strength was hypothesized and tested. The research data in this paper are drawn from patients' medical records (baseline characteristics, dysphagia screening results), and further quantitative data were acquired from the bedside assessment and the instrumental evaluation (please see the "Test methods" section for the index and reference tests). All new data from the swallowing examinations became part of the patients' medical documentation.

### *Research Questions*

From the stroke-related dysphagia care perspective the researchers raised the following questions:

1. Can diminished maximum anterior tongue elevation strength predict aspiration risk in acute stroke?
2. Can maximum anterior tongue elevation strength provide sufficient data to call for further instrumental assessment?
3. Should measurement of maximum anterior tongue elevation strength be a part of the noninstrumental swallowing assessment?

## Sample

Data were collected at our neurology unit (Department of Neurology—Stroke Centre, Saint John Central Hospital, Budapest, Hungary) and aimed to reach 30 cases. (For sample size calculation, please see the "Analysis" section.) Patients formed a consecutive series between November 2020 and February 2022 (16 months). The time from admission to assessment varied due to the patient's condition and the availability of instrumental assessment.

## Inclusion/Exclusion Criteria

Inclusion criteria were: definitive lesion(s) on neuroimaging diagnostics (Computed Tomography or Magnetic Resonance Imaging), stable medical condition $\geq 18$ years of age, and voluntary participation. Participants also had to be able to maintain a semisitting position in a bed for at least 30 min for the assessments. People who were unable to understand or execute oral motor tasks (e.g., low level of vigilance, sensory language deficits, oral praxis problems) were excluded. There was no case of pregnancy.

## Institutional Review Board Approval, Informed Consent, and Human Subjects' Rights

The study protocol was presented, and written consent was signed by all 30 subjects in accordance with the Helsinki Declaration. The procedures of this study were approved by the Hungarian Medical Research Council under license number: IV/2826-1/2021/EKU.

## Statistical Analysis

Statistical analysis was performed using the Jamovi software (*The Jamovi Project*, 2023) and SPSS (IBM SPSS Statistics for Windows, 2017). Descriptive data were calculated for sample characteristics. Methods for estimating measures of diagnostic accuracy were sensitivity, specificity, positive and negative predictive value, receiver operating characteristic (ROC), and area under the curve (AUC). In the sample, there were no indeterminate index test results or missing data. In order to keep type I. error (alpha) below 0.05, and type II. error (beta) below 0.2 (80% power), the researchers planned a total sum of 30 cases (Schoonjans, 2023). This calculation is in accordance with the publication of Akoglu and their freely available calculator (Akoglu, 2022).

## Test Methods

Dysphagia was screened after admission with the Gugging Swallowing Screen (GUSS; Trapl et al., 2007) which indicates instrumental assessment if the patient could not reach 20 points on the test. In some cases, self-reported dysphagia symptoms (e.g., food stuck in the "throat," fear of choking, painful swallowing) or mealtime observations were the indications of the instrumental evaluation. The SLP in agreement with the attending neurologist referred the case to the otorhinolaryngologist for instrumental evaluation.

Index test: Iowa Oral Performance Instrument (IOPI)

IOPI is a digital handheld pressure gauge that has an air-filled silicone bulb (approximately $3.5 \times 4.5$ cm) which is attached to it with an 11.5 cm long tube. Data were collected by the SLP while patients held a sitting position either in a chair or in bed. Values were recorded on a paper spreadsheet and appropriate protective gear was worn. The procedure was explained, and then, with the contribution of the patient, the bulb was placed on the alveolar ridge of the hard palate. The patient was kindly asked to push it with the apex of the tongue for a couple of seconds as hard as one could, while the screen displayed the result in kilopascal (kPa). Data were analyzed along the highest result of three trials (30-s rest between each) as suggested by the manufacturer which is called the $P_{max}$. The index test was performed prior to the reference test on the same day and the FEES operator was blinded for the IOPI results.

Reference test: FEES

An otorhinolaryngologist performed the reference test with the assistance of the SLP. During the process, the clinician passed a thin, flexible video endoscope (either the Ambu® aScope™ system with an aView™ monitor or a Karl Storz® Rhino Laryngo Fiberoscope 11,001 RD1 with a MOM® Fibrolux™ 150H light source) through the nose to the mesopharynx while multiple consistencies were given in order to examine the swallowing function. Consistencies were classified on the International Dysphagia Diet Standardisation Initiative (IDDSI; Cichero et al., 2017) scale and given in the following order: IDDSI 3 (thickened liquid)—IDDSI 0 (thin liquid)—IDDSI 7 (a piece of cracker). The first two consistencies were given with a syringe to control the amount (three trials on each quantity: 3–5–8 mL). The results of the FEES examination were interpreted on the Penetration-aspiration scale (PAS Scale; Rosenbek et al., 1996) between 1 and 8, where 1 point suggests no penetration, 2–5 points suggest penetration risk and 6–8 points suggest aspiration risk.

The procedure of the index and reference tests is shown in Figure 1.

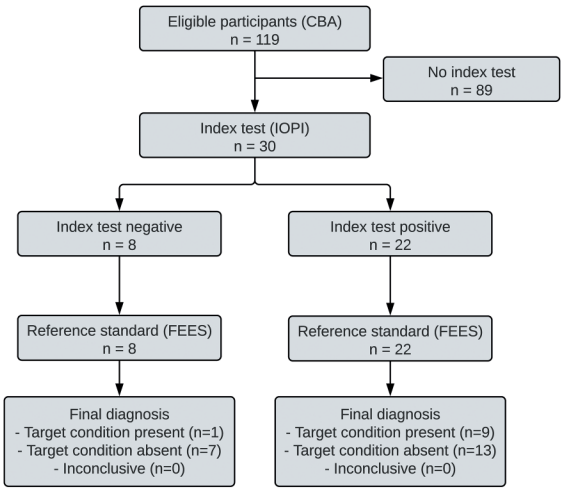


**Figure 1.** Flow of participants in the study according to the STARD guidelines. STARD = Standards for the Reporting of Diagnostic Accuracy Studies; CBA = clinical bedside assessment.

## Results

### Sample Characteristics

The sample ($n = 30$) included 12 women and 18 men. The mean age of participants was 73.6 years (*SD*: 12.4, min: 41, max: 93). Regarding stroke type, there were 25 ischemic and five hemorrhagic cases. In 15 patients the lesion was right-sided, 12 left-sided, and in further three cases, the lesions were bilateral. Out of the 30 cases, 24 subjects had central facial palsy. Stroke severity according to the National Institutes of Health Stroke Scale (NIHSS; Kwah & Diong, 2014) scale: eight subjects were in the "mild" (1–4 points), 15 in the "moderate" (5–15 points), and seven in the "moderate to severe" range (16–20 points). The mean NIHSS score was 9 in this sample. Table 1 presents the summary of the sample characteristics. According to the GUSS test, 13 patients had no dysphagia, one with mild, nine moderate, and nine severe. The average time from admission to the index and the reference test was 8.68 days. Regarding the IOPI measurement, the average pressure values were 27.5 kPa (min–max: 9–64 kPa; *SD*: 15.5) for $P_{max}$. The reference test; FEES was also carried out on each patient. The results were interpreted on the Penetration-aspiration scale (Rosenbek et al., 1996). The cut-off point for aspiration risk was a score of 6 on any trial (PAS $\geq$ 6). In our sample, according to the instrumental examination, the prevalence of aspiration risk was 33%. With 10 positive and 20 negative cases, the research accomplished the power analysis suggested distribution.

### Test Results

To assess the diagnostic accuracy of the index test, the $P_{max}$ values were compared to the FEES examination results.

**Table 1.** Baseline Demographic and Clinical Characteristics.

| Overview of the baseline demographic and clinical characteristics ($n = 30$) | |
|---|---|
| Gender | |
| Male | 18 |
| Female | 12 |
| Age (years) | |
| Mean (*SD*) | 73.6 (12.4) |
| Minimum–maximum | 41–93 |
| Stroke type (# of cases) | |
| Ischemic | 25 |
| Haemorrhagic | 5 |
| Site of lesion (# of cases) | |
| Right | 15 |
| Left | 12 |
| Bilateral | 3 |
| Stroke severity according to the NIHSS* (# of cases) | |
| Mild (1–4) | 8 |
| Moderate (5–15) | 15 |
| Moderate to severe (16–20) | 7 |
| Severe (21–42) | 0 |

NIHSS*: National Institutes of Health Stroke Scale.

Since there are no specific standards for stroke patients the researchers used the fifth and the first percentile cut-off point of the pooled normal values (>60 years; *IOPI Medical LLC*, 2023) namely 34 kPa and 25 kPa respectively for aspiration risk. It is important to note that for middle-aged persons (40–60 years) these scores are higher in a normal population, but the sample had only three patients younger than that, two with normal values and one with lower than 34 kPa (which was the highest used cut-off point). The analysis examined the diagnostic features of the IOPI measurements and aspiration risk on FEES (cut-off point: $\leq$ 34 kPa and PAS $\geq$ 6) and showed 90% sensitivity, 35% specificity, 41% positive predictive value, and 88% negative predictive value. The AUC for $P_{max}$ was AUC = 0.700 (95% CI [0.500–0.900]) The ROC curve is shown in Figure 2.

## Discussion

This study aimed to assess the diagnostic accuracy of $P_{max}$ to answer the following questions:

1. Can diminished maximum anterior tongue elevation strength predict aspiration risk in acute stroke?

   In this study, by using the normal curve's fifth percentile cut-off (34 kPa) the test reached 90% sensitivity. It needs to be added, that there was a patient with a strong tongue (50 kPa) who silently aspirated on the FEES. $P_{max}$ was not able to rule out this patient and it would make no sense to raise the cut-off value to 50 kPa since it falls between 25% and 50% of the normal curve, creating too many false positives. A recent study (Lee & Choi, 2020)

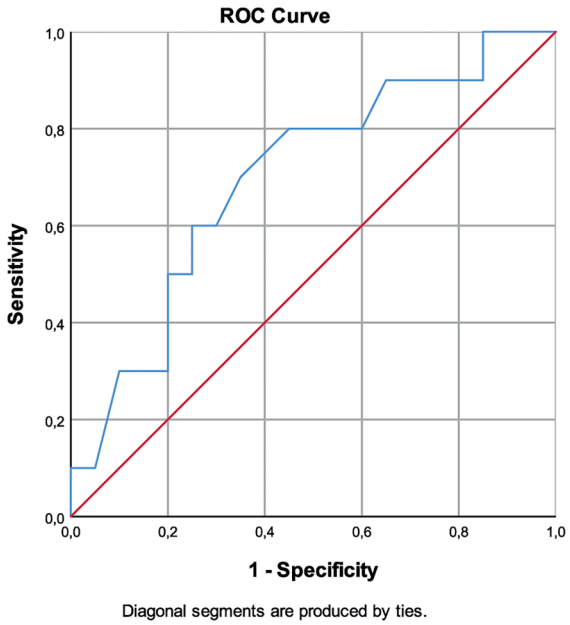


**Figure 2.** Receiver operating characteristic curve (ROC) for prediction of aspiration risk by $P_{max}$.

reported a similar study setting (although the sample characteristics and the incidence of aspiration differed significantly) and their highest cut-off value for aspiration was 15.5 kPa and reached 72% sensitivity, 77% specificity, 73% positive predictive value, and 75% negative predictive value. In designing a screening and/or an assessment the maximization of true positives (high sensitivity) and high negative predictive value should be aimed for. From this point of view, a higher $P_{max}$ value might be more optimal. Keskool found that at the cut-off value of 35 kPa, the diagnostic properties of anterior tongue elevation strength reached 92% sensitivity, 96% specificity, 92% positive predictive value, and 96% negative predictive value for aspiration (Keskool et al., 2018). This data also must be handled with caution in comparison to the recent findings, as in their dysphagic subgroup the underlying disease was only 64% cerebrovascular and the actual rate of aspiration on instrumental evaluation was not reported.

2. Can maximum anterior tongue elevation strength provide sufficient data to call for further instrumental assessment?

   In this study, 23/30 patients had diminished tongue strength but only 9 out of 10 among those who showed signs of aspiration on a FEES examination (14 patients did not). By combining the $P_{max}$ with the results of the <20 GUSS score, it turns out that the $P_{max}$ reduced the false positives from 10 to 8. This result is not sufficient alone, but all precise data is very valuable in bedside assessment while depicting a swallowing characteristic of a stroke patient, although such variables should not be interpreted separately. For example, an absent gag reflex could be an alarming sign of severe dysphagia, though a significant percentage of healthy adults have absent gag reflexes (Davies et al., 1995) and ongoing research is meant to explore its relevance in dysphagia screening (University of Giessen, 2023).

3. Should measurement of maximum anterior tongue elevation strength be a part of the noninstrumental swallowing assessment?

   Measurement of tongue strength is a promising instrumental aid in a stroke unit, and it is probably best suited in the comprehensive bedside assessment led by a dysphagia expert when there is more time for such assessments. For SLPs and specially trained nurses, it is important to have appropriate tools to evaluate the risk of aspiration and follow the patients' progression. This approach might potentially reduce the overuse of nasogastric tubes with consequent complications in the acute phase of stroke (Nascimento et al., 2018).

## Strengths and Limitations

As far as the researchers know this is the first study that tested the use of maximum anterior tongue elevation strength measurement in acute stroke for aspiration risk screening. One important limitation of this study lies in the fact that tongue elevation pressure measurement requires the active participation of the patient, filtering those who are really able to collaborate, which is a subgroup of all acute stroke patients.

## Implications for Practice

Tongue pressure is an objectively measurable value that is comparable with normative data (*IOPI Medical LLC*, 2023). The IOPI defines a base value which is a reference point for further tracing. It is also (and probably mainly) a training device in the rehabilitation phase. These kinds of instruments have some asset investment that needs to be calculated and the risk of minimal invasion and contact with the mucous of the oral cavity must also be considered.

## Conclusion

The researchers conclude that although individuals with low tongue strength tend to have a higher risk for aspiration, this variable alone is not capable of screening aspiration in acute stroke. In a comprehensive swallowing assessment, it might have the potential to reduce the number of false positive cases, in combination with a screener, but in this area, further work is required. If a stroke unit has an instrument such as the IOPI, which registers reliable data, low maximum anterior tongue elevation strength (< 34 kPa) can be a red flag during the assessment process and a baseline measurement is comparative for further follow-up in swallowing therapy.

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## Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Pál Tamás Szabó, Tímea Halász, and Viktória Műhelyi. The first draft of the manuscript was written by Pál Tamás Szabó and Viktória Műhelyi and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

## Data Availability

The data are not publicly available since they contain information that could compromise research participant privacy/consent.

## Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Informed Consent

Informed consent was obtained from all individual participants included in the study.

## Research Involving Human Participants and/or Animals

This study was performed in line with the principles of the Declaration of Helsinki.

## Statement of Ethics

Approval was granted by the Hungarian Medical Research Council under registration number IV/2826-1/2021/EKU.

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