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MISCELLANEOUS

The ability of the eating assessment tool-10 to detect penetration and aspiration in Parkinson's disease

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Abstract

Purpose Dysphagia is common in patients with Parkinson's disease (PD) and often leads to pneumonia, malnutrition, and reduced quality of life. This study investigates the ability of the Eating Assessment Tool-10 (EAT-10), an established, easy self-administered screening tool, to detect aspiration in PD patients. This study aims to validate the ability of the EAT-10 to detect FEES-proven aspiration in patients with PD.

Methods In a controlled prospective cross-sectional study, a total of 50 PD patients completed the EAT-10 and, subsequently, were examined by Flexible Endoscopic Evaluation of Swallowing (FEES) to determine the swallowing status. The results were rated through the Penetration-Aspiration Scale (PAS) and data were analyzed retrospectively.

Results PAS and EAT-10 did not correlate significantly. Selected items of the EAT-10 could not predict aspiration or residues. 19 (38%) out of 50 patients with either penetration or aspiration were not detected by the EAT-10. The diagnostic accuracy was established at only a sufficient level (AUC 0.65). An optimal cut-off value of ≥ 6 presented a sensitivity of 58% and specificity of 82%.

Conclusions The EAT-10 is not suited for the detection of penetration and aspiration in PD patients. Therefore, it cannot be used as a screening method in this patient population. There is still a need for a valid, simple, and efficient screening tool to assist physicians in their daily diagnostics and to avoid clinical complications.

Keywords Parkinson's disease · Dysphagia · Questionnaire · Screening

Introduction

Swallowing problems in Parkinson's disease (PD) patients are common and can occur even in early stages [1]. Up to 87% of the PD patients suffer from dysphagia [2, 3] with often severe consequences as reduced quality of life (QOL) [4], malnutrition [5, 6], and higher risk for pneumonia [7, 8]. In many cases, swallowing difficulties stay undetected until either patients are specifically asked about it or objective measurements like Flexible Endoscopic Evaluation of Swallowing (FEES) are applied [2, 9]. FEES or videofluoroscopy are considered the gold-standard methods in swallowing diagnostics [10, 11]. Non-invasive screening tools for quantifying dysphagia could be a resource-saving, quick alternative to the aforementioned gold-standard methods. However, although deeply needed, there is currently no validated dysphagia screening for PD patients. Even the initially promising "Munich dysphagia test—Parkinson's disease"

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proved to be unsatisfactory for screening due to a lack of sensitivity and insufficient detection of aspiration [12].

Not specific in PD but in dysphagia in general, the Eating Assessment Tool-10 (EAT-10) was internationally recognized and validated [13]. This self-administered 10-item questionnaire was found to have excellent internal consistency and test–retest reproducibility [13]. It has been validated to predict aspiration in adults with inter alia, Chronic Obstructive Pulmonary Disease (COPD), and Amyotrophic Lateral Sclerosis (ALS) [14, 15]. The EAT-10 has since been translated into several different languages, among them French, German, and Arabic [16–18].

Materials and methods

Standard protocol approvals, registrations, and patient consents

This prospective cross-sectional study was conducted at the University Medical Center Hamburg-Eppendorf between January and May 2019. The study was approved by the local ethics committee of the Medical Council Hamburg and has, therefore, been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Written informed consent was obtained from all participants or, in case of care provided, by their legally authorized representative.

Subjects

A cohort of Parkinson patients of all clinical Hoehn and Yahr stages who presented themselves at the outpatient clinic for movement disorders or underwent inpatient treatment was recruited consecutively and examined prospectively. To keep selection bias, as low as possible patients were enrolled in this study regardless of self-reported swallowing problems. A total of 61 patients with a confirmed PD diagnosis according to the UK bank brain criteria [19] consented and 50 of them were included in this study. The exclusion criteria were atypical or secondary Parkinson syndromes and other diseases accompanied by dysphagia, such as head and neck cancer as well as a history of ischaemic stroke, which might also affect swallowing capacities.

Procedure

All patients were examined at a single visit in the Department of Voice, Speech and Hearing Disorders. Examinations were conducted in the clinical "on"-stage. The clinical "on"-stage describes the patient's state 1 h after the medication intake. The severity of motor symptoms was assessed according to the new revised Movement Disorder Society version of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS) part III [20] and Hoehn and Yahr Scale (H&Y) [21]. Cognitive function was evaluated using the Montreal Cognitive Assessment (MoCA) [22]. The Levodopa equivalent dose was calculated according to Tomlinson et al. [23]. All subjects completed the EAT-10 [13] with the assistance of a research associate when required. They had to answer the ten symptom-specific items based on a scale from 0 to 4 (0 = no problem and 4 = serious problem). Furthermore, they were asked if they had suffered from pneumonia within the last 2 years and if they had shown any clinical aspiration markers, e.g., coughing or clearing one's throat at or shortly after eating or drinking. Affirmations were noted as positive aspiration signs. Subsequently, subjects underwent FEES examination [24] performed by experienced (> 15 years) otorhinolaryngologists using a 2.6 mm-diameter high-definition rhino-laryngo videoscope (ENF-V3, Olympus Medical Systems Corp., Tokyo, Japan). During FEES, the subjects were given standardized test boluses in a fixed order. First, three teaspoons of thickened water were administered. Then, they were asked to drink successively 5 ml, 20 ml, 50 ml, and 90 ml of water rapidly with a straw. Finally, subjects were requested to eat a slice of bread with butter ($\approx 6 \times 40 \times 30$ mm, weight 11 g). Each examination was recorded on video (MediCap USB300 (MediCapture, Plymouth Meeting, PA, USA)) and evaluated afterward.

Data analysis

The FEES videos were rated by two independent examiners (more than 15 years experienced physicians from the Department of Voice, Speech and Hearing Disorders) blinded for each patient's clinical stage and the other one's results. The occurrence of penetration or aspiration was classified using the Penetration-Aspiration Scale (PAS) [25]. For further data analysis, the worst PAS score of each consistency and patient was selected and patients were classified into two groups (without aspiration: PAS < 6, with aspiration: PAS ≥ 6), respectively, three groups (with safe swallowing: PAS 1, with penetration: PAS 2–5, with aspiration: PAS 6–8). PAS 6–8 scores implicate an aspiration with the potential of causing pneumonia. The severity of residues was evaluated according to the validated Yale Pharyngeal Residue Severity Rating Scale [26]. Relevant residues were defined from a severity degree of 4 or more ("moderate"). One patient was not able to swallow the bread which he was administered. Therefore, this question comprised only 49 patients instead of primal 50 (Table 1).

According to Belafsky et al., the total EAT-10 score was calculated from the sum of the ten items (score range: 0–40) [13, 17]. Total scores of 3 or higher were considered pathological and patients were divided into two groups accordingly (EAT-10 < 3, EAT-10 ≥ 3). To assess the interrelation

Table 1 Subject characteristics of PD patients, categorized in subjects without aspiration (PAS < 6) and with aspiration (PAS ≥ 6)

	Patients ($n=50$) mean ± SD or N (%)	A, PAS < 6 ($n=38$) mean ± SD or *N* (%)	B, PAS ≥ 6 ($n=12$) mean ± SD or *N* (%)	*p* values A < > B
Age (years)	69.5 ± 9.4	68.8 ± 9.0	71.9 ± 10.6	0.32[a]
Men	34 (68%)	23 (60.5%)	11 (91.7%)	0.07[b]
MOCA (score)	25.4 ± 4.1	25.9 ± 3.7	24 ± 5.1	0.16[a]
- Cognitive deficit (i.e., MOCA < 26 points)	19 (38%)	13 (34.2%)	6 (50%)	0.5[b]
Disease duration (years)	9.7 ± 5.8	9.4 ± 6.2	10.6 ± 4.0	0.46[a]
Hoehn and Yahr				0.21[c]
- Stage 1	1 (2.0%)	1 (2.6%)	0 (0.0%)	
- Stage 2	28 (56%)	23 (60.5%)	5 (41.7%)	
- Stage 3	15 (30%)	10 (26.3%)	5 (41.7%)	
- Stage 4	5 (10%)	3 (7.9%)	2 (1.7%)	
- Stage 5	1 (2%)	1 (2.6%)	0 (0%)	
MDS-UPDRS				
- Motor score (III)	27.6 ± 14.2	27.4 ± 14.6	28.2 ± 13.3	0.86[a]
DBS	15 (30%)	12 (31.6%)	3 (25%)	1.000[b]
LED (mg)	922 ± 475	886 ± 468	1036 ± 498	0.35[a]
History of aspiration signs	21 (42%)	15 (39.5%)	6 (50%)	0.74[b]
History of pneumonia	3 (6%)	2 (5.3%)	1 (8.3%)	1.000[b]
EAT-10 score	4.2 ± 5.9	3.7 ± 5.9	5.9 ± 6.2	0.25[a]

MOCA Montreal cognitive assessment, *MDS-UPDRS* Movement Disorder Society-sponsored revision of the unified Parkinson's disease rating scale. *DBS* Deep Brain Stimulation, *LED* Levodopa equivalency dose according to Tomlinson et al. *EAT-10* Eating Assessment Tool-10 according to Belafsky et al. Intergroup differences were tested with [a]*t* test [b]Fisher's exact test, and [c] Kruskal–Wallis test. Significant differences were assumed when *p* values are less than $\alpha = 0.05$

of EAT-10 with PAS and residues, separate sum scores on items 3 ("Swallowing liquids takes extra effort") and 9 ("I cough when I eat"), as well as 4 ("Swallowing solids takes extra effort") and 8 ("When I swallow food sticks in my throat") were combined (EAT 3 + 9, EAT 4 + 8). Sum scores ≥ 4 were considered pathological.

Statistical analysis

For continuous data mean values and standard deviations were calculated. Differences between groups were analyzed using the *t* test for independent samples or one-way analysis of variance (ANOVA) for more than two groups. Confidence intervals and *p* values for subgroups comparisons were adjusted with Bonferroni. To estimate and compare frequencies of nominal- and ordinal-scaled data, Fisher's exact test was applied. To assess differences between central tendencies of several independent samples, Kruskal–Wallis test was applied. All correlations are based on Bravais–Pearson. Binary logistic regression analysis was carried out to determine if PAS scores were associated with EAT-10 scores. A receiver-operating characteristics (ROC) curve was generated to determine the diagnostic accuracy and optimal cut-off value for the EAT-10. Thus concomitant, the area under the curve (AUC), sensitivity, specificity, and 95% confidence intervals (CI) were calculated. Interrater reliability was determined by Bravais–Pearson's correlation coefficient. All statistical tests were two-tailed. The significance level was set to $\alpha = 0.05$. The statistical software package SPSS, version 26 (IBM, USA) was used to carry out statistical analyses.

Results

The demographic and clinical data are shown in Table 1.

The interrater reliability of the FEES rating was with a Pearson correlation coefficient of $r = 0.866$ ($p < 0.001$) high. 24% of all 50 patients showed aspiration in FEES (PAS ≥ 6), with swallowing liquid consistency leading to the highest PAS scores. (Fig. 1) Although the patients with aspiration achieved a higher EAT-10 score (mean 5.92 ± 6.16) than those without (mean 3.66 ± 5.82), the inter-group difference was not significant (−2.259, $p = 0.253$, CI [−6.185–1.668], Fig. 1). Mean EAT-10 scores did not differ significantly between subgroups ($p = 0.261$). Subgroup comparisons reveal low differences between low and high PAS scores (0.69, 95% CI [−5.35, 6.53], $p = 1.000$) while the middle group has considerably lower values than the others (safe swallowing 2.39, 95% CI [−2.59, 7.18], $p = 0.719$)

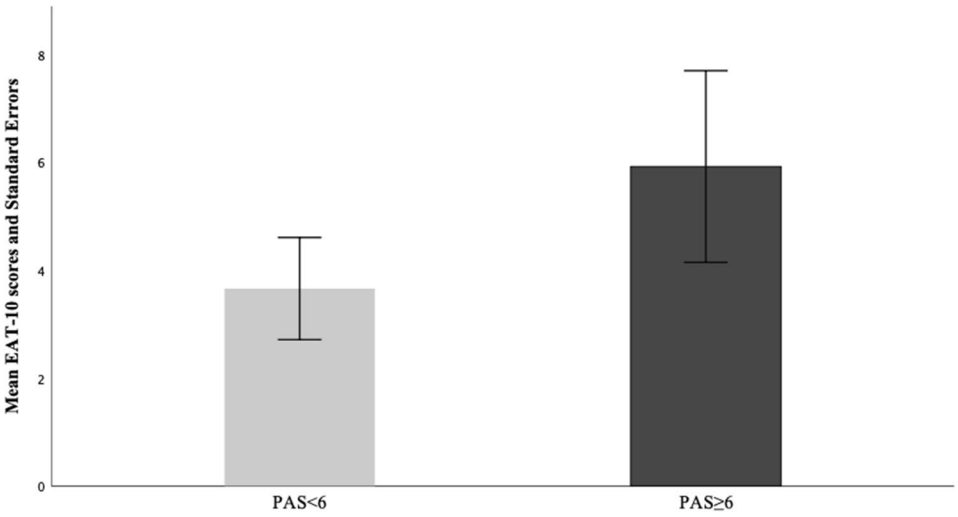

Fig. 1 EAT-10 from individuals who did not aspirate (PAS < 6) and those who did (PAS ≥ 6)

(aspiration 3.08, 95% CI [−2.04, 8.20], $p = 0.417$). Moreover, EAT-10 and PAS scores do not correlate significantly ($r = 0.043$). Even the logistic regression analysis shows no significant association of EAT-10 and PAS scores (OR 1.059, (CI [0.957, 1.171], $p = 0.226$). Of the 27 patients with an inconspicuous EAT-10 score (score < 3), 8 presented safe swallowing (PAS 1), 14 penetration (PAS 2–5), and 5 had aspiration (PAS 6–8) in FEES. Thus, 70% of the subjects with penetration or aspiration were not detected by the EAT-10 (Table 2). Especially in subjects with high PAS values, a positive answer to items 3 and 9 of the EAT-10 would be expected. However, the correlation analysis showed no significant coherence between the PAS and the EAT 3 + 9 sum score ($r = 0.057$, $p = 0.694$).

Out of 49 subjects, 22 (45%) of those who reported problems swallowing solids by responding positively to EAT-10 items 4 and 8 had an increased residue score on the Yale Pharyngeal Residue Severity Rating Scale [26] with residues in either the region of vallecula or sinus piriformis (Fig. 2). Correlation analysis shows that there is a significant but low association between the EAT 4 + 8 sum score and the residue severity in the vallecula ($r = 0.339$, $p = 0.017$). Only 3 out of 21 (14%) patients with vallecula residues reached an EAT 4 + 8 sum score ≥ 4. The one patient with only residues in sinus piriformis had no conspicuous EAT 4 + 8 sum score (Fig. 2). Patients with FEES-proven aspiration compared to those without present no significant differences in MDS-UPDRS III (−0.262, $p = 0.795$, [CI −0.1593–0.1226]). The differences in MDS-UPDRS III and participants with EAT-10 scores < 3 and ≥ 3, respectively, were significant (−2.415, $p = 0.020$ [CI −0.2512, −0.0229]), meaning that a greater motor impairment in PD can be associated with higher EAT-10 scores. Patients with higher EAT-10 scores reported a higher occurrence of aspiration signs (65.2% vs. 22.2%, $p = 0.004$) (Table 2; Fig. 2).

According to the created ROC curve, the EAT-10 presents a poor diagnostic accuracy for predicting aspiration in PD patients (AUC = 0.65, SE = 0.096, $p = 0.117$, CI [0.463–0.839]) (Fig. 3). Based on the calculated sensitivity and specificity values for each EAT-10 score, an optimal cut-off value of ≥ 6 demonstrated the highest diagnostic accuracy (sensitivity 0.583 and specificity 0.184) (Fig. 3; Table 3).

Discussion

This prospective study shows that the EAT-10 alone is unable to predict aspiration and penetration with sufficient accuracy in PD patients. With a sensitivity of 58% and a specificity of 82% for the optimal cut-off value of ≥ 6, the EAT-10 is not able to identify even PD patients with severe dysphagia. Although individuals with aspiration achieved higher EAT-10 scores on average than those with safe swallowing, differences were only marginal. Patients with penetration were found to have considerably lower scores than both subjects with aspiration and safe swallowing.

Table 2 Distribution of subjects based on PAS and EAT-10 score

EAT-10 scores	PAS 1 (safe swallowing)	PAS 2–5 (penetration)	PAS 6–8 (aspiration)	Total
< 3	8 (29,6%)	14 (51,9%)	5 (18,5%)	27 (100%)
≥ 3	5 (21,7%)	11 (47,8%)	7 (30,4%)	23 (100%)
Total	13 (26%)	25 (50%)	12 (24%)	50 (100%)

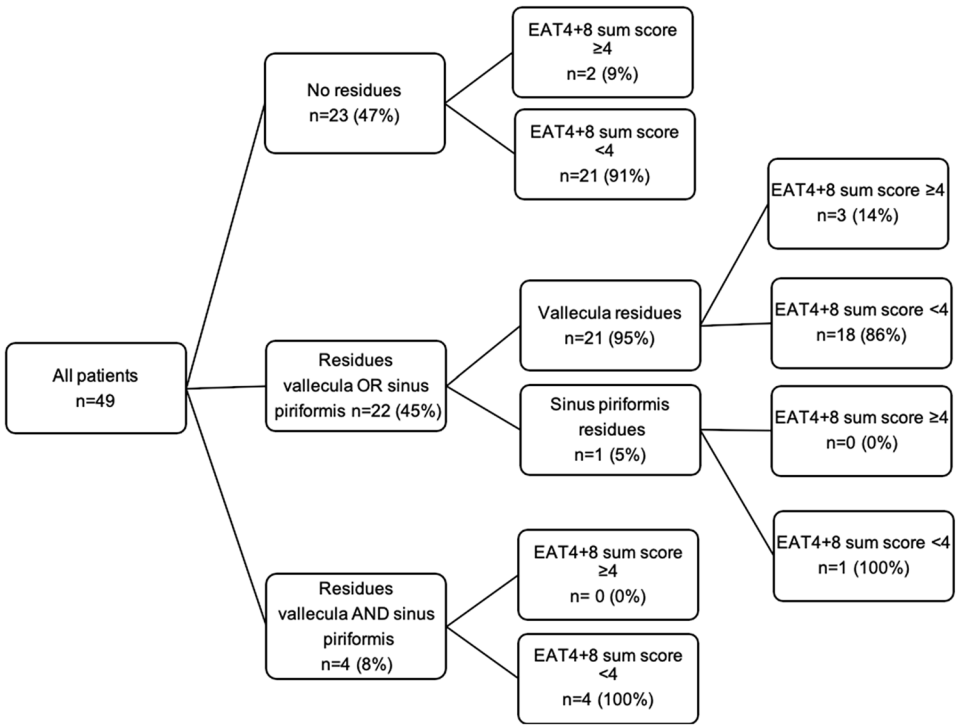

Fig. 2 Residues in conjunction with EAT-10 sum score of items 4 and 8 (EAT 4 + 8)

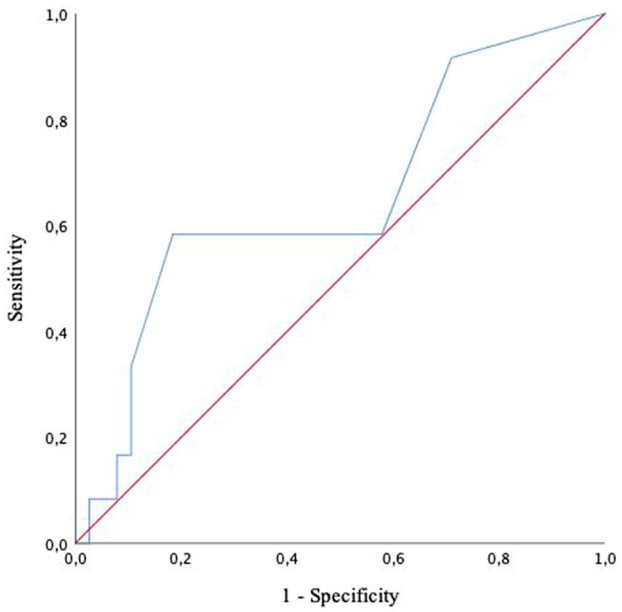

Fig. 3 ROC curve

Table 3 Coordinates of the ROC curve

EAT-10 score	Sensitivity	1-specificity
−1.00	1.000	1.000
.50	.917	.711
1.50	.583	.579
2.50	.583	.421
3.50	.583	.316
4.50	.583	.211
5.50	.583	.184
6.50	.417	.132
7.50	.333	.105
8.50	.167	.105
9.50	.167	.079
11.00	.083	.079
15.50	.083	.053
20.50	.083	.026
26.00	.000	.026
31.00	.000	.000

The grayed value is the EAT-10 score with the highest sensitivity and specificity, indicating that 6 is the optimal cut-off value to detect aspiration in PD patients

Interestingly, our findings differ significantly from recently published studies in other patient cohorts, in which the EAT-10 scores correlate with aspiration and penetration in the FEES [14, 15, 27]. Assessing the utility of the EAT-10 to predict aspiration in adults with Chronic Obstructive Pulmonary Disease (COPD) [15] or Amyotrophic Lateral Sclerosis (ALS) [14], there were not only major differences in patients with aspiration and those without but also higher mean values per se. What distinguishes these patient cohorts from PD patients are different impairments of the swallowing pattern depending on the disease. Individuals with

ALS experience a degeneration of respiratory musculature which has a direct impact on airway protection and laryngeal clearance [28, 29], whereas the sensitivity is on no account impaired. Additionally, ALS patients are reported to have difficulties with the oral phase of swallowing, even in the early stages of the disease [30, 31]. However, dysphagia in PD patients is insufficiently or often not perceived [2, 32] in any clinical stages of the disease, although patients experience a similar motor impairment [33]. This may be the reason for lower EAT-10 scores in PD than in ALS patients. Furthermore, PD is associated with cognitive deficits [34], unlike ALS and COPD. The ability of self-perception and, in the case of more severe deficits, also the ability to report may be limited. This may also result in a different score of the EAT-10 questionnaire. The EAT-10 is not suitable for detecting swallowing problems caused by reduced sensitivity—not only for Parkinson's disease, but also for any patient with sensitivity disorders.

PD patients often lack the laryngopharyngeal sensitivity due to pathological processes in sensory nerves to notice whether residues are fully cleared or remain in their throat after swallowing [35]. In addition, PD patients often have diminished cough sensitivity [36–38], which reduces pharyngeal clearance and promotes silent aspirations. Similar symptoms can be observed in patients with COPD, especially with acute exacerbation of COPD [39, 40]. Nevertheless, the mean EAT-10 results differ considerably between both patient cohorts. A possible explanation could be found in the cohort compositions. There was a different distribution of COPD severity levels (mild, moderate, and severe) and, in our case, the severity of PD. A larger cohort size would be required to validate the outcome. Although the symptom complexes of both patient collectives overlap strongly, COPD patients are more focused on their aerodigestive tract and associated pathologies. Furthermore, it must be considered that the EAT-10 is a screening tool that asks patients about their subjective swallowing problems and only in one item explicitly asks about possible aspiration or penetration ("I cough when I eat"). In addition, patients answered differently depending on individual and external circumstances. Different levels of support from the research associate in completing the EAT-10 may also have led to differences in results between patient collectives. This is in line with the findings from Cordier et al. who put forward concerns about significant weaknesses in structural validity, internal consistency, and item redundancy [41].

Despite the presence of clinical aspiration signs, 11 patients with laryngeal penetration were not detected through the EAT-10. This is in line with the analysis of Kean et al. [42] and Cordier et al. [41] who stated that the EAT-10 is only able to distinguish between low and high dysphagia severity levels. This is the reason why many patients who showed penetration (PAS 2–5) remain undetected by the EAT-10. However, the explicit question concerning aspiration signs ("Did you experience any aspiration signs, e.g., coughing or clearing one's throat at or shortly after eating in the recent past?") could in the future be a supplement to dysphagia detection [43]. Differences between the groups of individuals with aspiration and those without, regarding history of aspiration events, were established as not significant. This indicates that silent aspiration, as is common in PD patients [1], could be an explanation.

The results of our study suggest that a higher MDS-UPDRS III is associated with a higher EAT-10 score. This can be explained by our observation that patients with more severe motor impairment rate certain EAT-10 items particularly high, for example, items 1 ("My swallowing problem led to weight loss") and 2 ("My swallowing problem affects my ability to go out for dinner"). According to Wilmskoetter et al. [44], items 1 and 2 are very rarely answered as conspicuous as they are not describing common symptoms in the dysphagia symptom complex. In our study, the particularly high scores of items 1 and 2 are probably not due to dysphagia per se but rather to restrictions due to PD itself.

Regan et al. [15] recommended that specific questions of the EAT-10 be tested for their predictive ability. We examined the explicit influence of items 3 and 9 on the PAS score and found no significant correlation. Item 3 "Swallowing liquids takes extra effort" implies that the muscular involvement in the act of swallowing is not working properly. However, since PD is not a motoneuronal disease, a result different from the one observed within this study would be surprising. Item 9 ("I cough when I eat") should be classified as critical, especially in Parkinson patients. It has been proven that these patients have a higher stimulus threshold for the cough reflex, which may not trigger a reflex even if aspiration is present [36]. Besides, as already described, there is often a reduced laryngopharyngeal sensitivity in which patients do not even notice that residues remain in their throat [35].

Residues in the vallecula and the associated two EAT-10 items 4 and 8 correlated significantly, although only 3 of the 21 individuals had an EAT4 + 8 sum score ≥ 4. That is surprising giving the fact that pharyngeal residues are the most common symptoms in PD patients [1, 45]. For a hypothetical cut-off of ≥ 3, the number of those who were conspicuous in the EAT 4 + 8 sum score did not change significantly. However, the reason for this surprising significance is likely the subjective evaluation and the associated response to these items. A change in the residue score is accompanied by a higher EAT-10 sum score, but the change only occurs in the lower evaluation spectrum, not exceeding the cut-off of 4.

In conclusion, our prospective study was conducted to determine the predictive capability of the EAT-10 for detecting aspiration in PD patients. According to our investigations, the EAT-10 is neither able to predict aspiration nor

penetration with sufficient sensitivity. Selected individual items of the EAT-10 fail to show a correlation between symptoms and clinical relevance. Thus, we cannot recommend the use of EAT-10 as a screening tool for Parkinson patients. Particularly in cases of swallowing problems due to reduced sensitivity, the EAT-10 is not suitable as a screening tool for severe dysphagia—not only for Parkinson's disease, but also for any patient with sensitivity disorders. The need for sensitive, easy-to-use screening tools, therefore, continues to exist.

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Code availability Not applicable.

Compliance with ethical standards

Conflicts of interest The authors have no conflict of interest to report.

Ethical standards The study was approved by the local ethics committee of the Medical Council Hamburg (trial number PV5089) and has, therefore, been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Consent to participate Written informed consent was obtained from all persons.

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