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ORIGINAL ARTICLE

The Modified Barium Swallow Impairment Profile as a Predictor of Clinical Outcomes of Admission for Pneumonia or Choking in Dysphagic Patients with Parkinson's Disease

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Abstract

Dysphagia increases risk of pneumonia in patients with Parkinson's disease (PD). However, no studies have investigated the association between objective measures of swallowing dysfunction and clinical outcomes. Therefore, we aimed to study the link between scores obtained on the modified barium swallow impairment scale profile (MBSImP) and hospital admissions for pneumonia and choking, in groups of patients with PD on different feeding modes. 157 patients who completed MBS studies were divided into three groups based on their feeding modes (oral, enteral, and rejected enteral feeding with oral feeding at own risk). Videos were analysed using the MBSImP. We evaluated the association of the oral, pharyngeal, and combined scores, with risk of admission for pneumonia and choking. Kaplan–Meier plots and log-rank tests were used to compare survival distributions among feeding groups. Cox regression models were generated to estimate hazard ratios (HRs) and 95% confidence intervals. Patients in the group that rejected enteral feeding scored the highest on the MBSImP, followed by enteral then oral feeding. Within the group that rejected enteral feeding, higher pharyngeal (HR = 3.73, $p = 0.036$) and combined scores (HR = 1.63, $p = 0.034$) significantly increased the risk of pneumonia and choking. In the enteral feeding group, higher oral subscores (HR = 2.16, $p = 0.011$) increased risk for the event, while higher pharyngeal (HR = 0.40, $p = 0.004$) subscores reduced risk for pneumonia and choking. This is the first study to analyse the association of MBSImP scores with clinical outcomes in PD patients. Patients who rejected enteral feeding had the highest risk for pneumonia and choking that could be predicted by their MBSImP scores. In the enteral feeding group, this risk was partially reversed. Compliance with feeding modes reduces the risk of pneumonia and choking.

Keywords Parkinson's disease · Deglutition · Deglutition disorders · Modified barium swallow · Modified barium swallow impairment profile · Pneumonia · Clinical outcomes

Introduction

Patients with Parkinson's disease (PD) are three times more likely to have dysphagia in comparison with healthy individuals [9], with bradykinesia and muscle rigidity, the hallmarks of PD, as underlying contributing factors [3, 20]. The modified barium swallow (MBS) is widely used in research studies investigating various parameters of dysphagia in patients with PD [1, 2, 4, 6, 16, 18]. In these studies, oral and pharyngeal phase dysfunction in patients with PD were described as lingual tremor and pumping, reduced anterior–posterior tongue movements associated with poor bolus formation, propulsion and control; delayed swallows, and reduced pharyngeal constriction with pharyngeal retention indicated by residue at the vallecular space, pyriform sinus and pharyngeal wall, with associated aspiration and penetration [1–6, 16]. Pharyngeal residue in the vallecular space, residue in the upper oesophageal sphincter and piecemeal deglutition were found to be significant predictors of aspiration and penetration in patients with PD [3].

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Despite knowledge of these physiological descriptors of dysphagia derived from MBS studies conducted in patients with PD, there is still a limited understanding of how the impaired swallowing mechanism may directly associate with clinical outcomes in patients in PD. Existing literature only showed the occurrence of aspiration and/or penetration as associated with an increased relative risk of pneumonia in patients with PD [11, 17, 21]. Lee et al. [11] took a first step in investigating the relation of swallowing patterns to clinical outcomes of aspiration pneumonia in patients with PD by implementing the Functional Dysphagia Scale (FDS), to quantify the severity of dysphagia based on scores given for 11 variables [8]. The findings revealed higher scores on the FDS for patients who had aspiration pneumonia, ideally supporting the use of the FDS in predicting the occurrence of aspiration pneumonia in patients with PD. However, it is worthy of note that the FDS, which was originally based on swallowing patterns specifically in a stroke population [8], was developed and scored by physicians rather than speech language pathologists who are considered experts in the field of dysphagia. Furthermore, the study population was only limited to patients on oral feeding and did not account for those on enteral or oral feeding despite aspiration risk [11]. Therefore, this last study may not be entirely representative to (i) describe the full extent of the swallowing profile which speech language pathologists regularly examine, and (ii) represent the population of patients with PD who may be on other modes of feeding as a result of dysphagia diagnosed.

Our study team had completed the first study to investigate the risk and prognostic factors for clinical outcomes of pneumonia and choking amongst patients with PD with dysphagia who had undergone a modified barium swallow [7]. This is in line with aspiration pneumonia being one of the most common causes of hospitalisation and mortality in patients with PD [14]. Findings had revealed that the 'type of feeding mode' recommended post MBS is one of the important risk factors for pneumonia or choking. The hospital admission rate for patients on full oral feeding at own risk after rejection of enteral feeding was the highest, then by patients on full enteral feeding, and then followed by patients on full oral feeding where recommendations ranged from regular-to-modified food textures and fluids [7]. With the association of the type of feeding mode to clinical outcomes of pneumonia and choking established, it is now valuable to investigate at a deeper level, how the swallowing mechanism dysfunction in this group of patients with PD directly relates to clinical outcomes, with the use of an objective tool.

Therefore, the study team decided to undertake this follow-up study, using the modified barium swallow impairment scale profile (MBSImP) as the objective evaluation tool given its use previously in the PD population [10]. At a more descriptive level, the MBSImP quantifies 17 physiological and bolus flow components pertaining to oral, pharyngeal and oesophageal functions in the swallowing mechanism [13]. It is a standardised evaluation tool that was developed by a multidisciplinary team dominated by speech language pathologists, with high inter- and intra-reliability following standardised training. The MBS was also rigorously trialled in a heterogeneous, representative and cross-sectional sample of patients and allows for the assessment of swallow physiology irrespective of diagnosis [13]. By implementing the MBSImP, we aim to study the link between the scores obtained on the MBSImP and hospital admissions for pneumonia and choking, in groups of patients with PD on different feeding modes.

Method

Study Population

Patients with Parkinson's disease who had completed a modified barium swallow between 1 January 2010 and 31 December 2014 were retrospectively recruited for the study. These patients were identified from the databases of the radiology department at Tan Tock Seng Hospital and the Movement Disorders Clinic of the National Neuroscience Institute (NNI). Their clinical diagnosis of PD was made by movement disorders specialists, and adheres to the diagnostic criteria defined by the National Institute of Neurological Disorders and Stroke (NINDS). All eligible patients were on enteral feeding for less than 3 months or on oral feeding prior to the MBS. The electronic medical records system that links admission records for all public hospitals in Singapore was reviewed to ensure that all public hospital admissions for pneumonia or choking had been captured. Only Singapore citizens or permanent residents were recruited in order to ensure that there was sufficient follow-up and information on admissions for pneumonia and choking was accessible. Baseline demographical information obtained at or within 2 years from the entry point of the study was recorded. This included gender, ethnicity, age, disease duration, Hoehn and Yahr (H&Y) stage, and the unified Parkinson's disease rating scale-III (UPDRS-III) scores. As the MBS may have been completed as an outpatient episode or during an inpatient stay, patients were excluded from the study if they developed any other medical condition resulting in significant dysphagia prior to the MBS; or if their PD diagnosis was revised during the follow-up period.

The entry point to the study was the date of each participant's first MBS. Study participants were divided into three broad group categories based on their recommended and agreed mode of feeding:

Group A—patients on full oral feeding:

- MBS study concluded with recommendations of full oral feeding of diet and fluids, ranging from regular-to-modified diet textures and thin to thickened fluids.

Group B—patients on full enteral feeding:

- MBS study concluded with recommendations of full enteral feeding, due to significant dysphagia with associated aspiration risk on oral feeding.

Group C—patients on full oral feeding at own risk, after rejecting enteral feeding

- MBS study concluded with recommendations of full enteral feeding, due to significant dysphagia with associated aspiration risk on oral feeding. However, patients chose to continue with full oral feeding at their own risk.

These three group categories were identified in consideration that 'type of feeding mode' recommended after an MBS study was recognised one of the important risk factors for pneumonia or choking in our prior study [7].

Modified Barium Swallow

As per hospital protocol, patients with Parkinson's disease presenting with signs of aspiration on clinical swallowing assessment (i.e. recognised as wet voice, significant desaturation, and throat noises on cervical auscultation based on our clinical experience), oesophageal phase dysfunction (i.e. presenting with complaints of globus sensation, excessive burping, and gurgly throat noises based on our clinical experience), and/or a history of repeated admissions for pneumonia (> 1) are routinely referred for a modified barium swallow (MBS).

The MBS is conducted by a trained speech language pathologist in conjunction with a radiologist using an established hospital protocol (Fig. 1). The procedure is typically performed with the patient seated upright on a Hausted Chair, with fluoroscopic imaging in the lateral view, video recorded at 30 frames/s. Patients are fed a range of hospital standardised fluid consistencies (thin, nectar-thick, honey-thick, pudding-thick) and diet textures (blended, soft and moist, regular). To achieve the consistency of thickened fluids, fruit cordial is mixed with E-Z-HD Barium sulphate for suspension (98% w/w), and thickened with Valens Thixer,

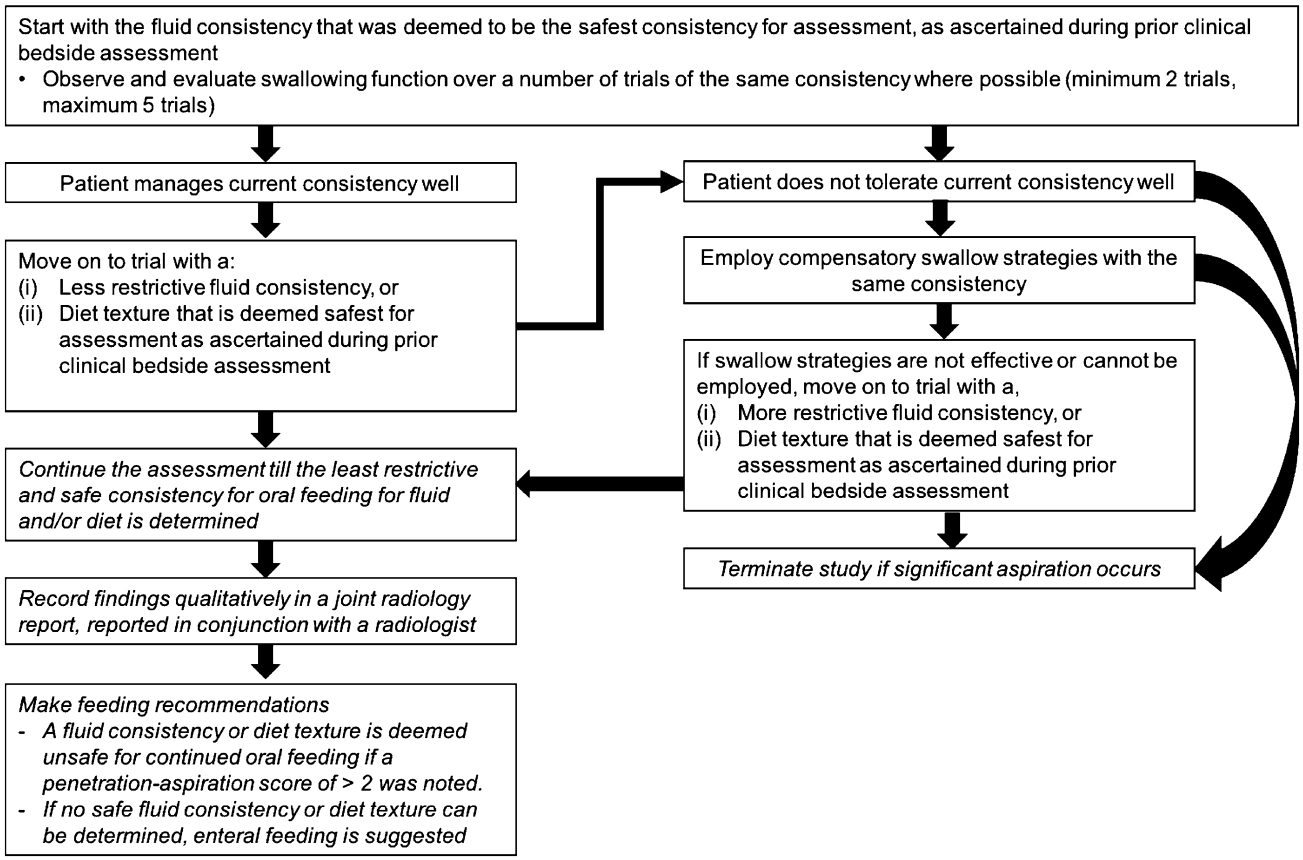

Fig. 1 Hospital protocol of the decision-making process during modified barium swallow

a modified food starch. For diet, blended rice porridge, soft and moist rice porridge, and regular textured rice or biscuits are coated with barium. Feeding measures (teaspoon, tablespoon, straw drinking, and cup drinking) and the number of trials administered per fluid consistency and diet texture are decided upon by the speech language pathologist, determined based on a patient's known swallowing impairment from prior clinical assessment, and calculated risks of aspiration as the MBS procedure progresses. For the recruited patients, the duration of each MBS study was approximately 15–20 min, with a minimum of between 2 and an average of 5 boluses administered for each measure of fluid consistency or diet texture trialled.

The MBS video clips were analysed, in a blinded manner, by two speech language pathologists trained in using the MBSImP scale. Both raters had varied number of years in clinical experience (2 years and 8 years) and were blinded to baseline demographical information, feeding measures (teaspoon, tablespoon, cup, straw), swallowing pathophysiology as well as outcome feeding recommendations that were established at time of study. The modified barium swallow impairment profile (MBSImP), a standardised evaluation tool, was used to objectively evaluate the swallowing profile across 17 physiological components characterising oral, pharyngeal and oesophageal impairments [13]. Upon analysis of each MBS clip, each physiological component was given an overall impression (OI) score based on a 3 to 5-point scale. This OI represented the most impaired score observed across all fluid consistencies, diet textures and feeding measures. A score of 0 reflects normal physiology, and each subsequent increase in score point describes a distinguishable swallowing characteristic that progresses to a maximum score of 3 to 5 that is reflective of severe deficits in physiology [13]. In the case of missing scores due to factors pertaining to non-optimal patient positioning and safety reasons, these components were scored as 'Cannot Assess'. Missing values were noted for (i) Component 1 (lip closure), due to poor image capture due to non-optimal positioning resulting in omitted visualisation of the lips in the lateral view, and (ii) Component 3 (bolus preparation/mastication), when textured diet that required chewing was not fed due to safety reasons or patient refusal.

The following three components were omitted due to the established hospital procedure practices as described: (i) Component 2 (tongue control during bolus hold) was removed as patients were not instructed to hold the bolus in their mouth and cued to swallow; (ii) Component 13 (pharyngeal contraction) was removed as this component requires the patient positioned in the anterior–posterior view, and the MBS was only performed in the lateral view; (iii) Component 17 (oesophageal clearance) was removed as it was not routinely assessed, but only addressed in a very small group of patients who were suspected to have oesophageal phase deficits based on prior clinical assessment. With these omissions, total scores for oral phase impairments ranged between 0 and 19, while total scores for pharyngeal phase impairments ranged between 0 and 26, depending on severity.

Statistical Analyses

We evaluated the association of oral score and pharyngeal subscale scores with the risk of admission for pneumonia and choking, with time to event (admission for pneumonia or choking) being the primary outcome. To limit survival bias, the date of the first MBS during the studied period was considered as baseline. For cases with admission for pneumonia or choking, time to event was defined as the time elapsed between baseline MBS assessment and the first admission for pneumonia or choking, between January 1, 2010 and September 30, 2015. For cases with no admission for pneumonia or choking, information was censored. Time to censoring was defined as the time between the baseline MBS assessment till death from causes other than pneumonia or choking, another medical condition contributing to dysphagia that occurred during the study period, or when the study reached the end date without event. Kaplan–Meier plots were generated and log-rank tests were used to compare the survival distributions between the feeding groups. Cox regression models were developed separately for the oral and pharyngeal subscale scores, to estimate the hazard ratios and 95% confidence intervals. All tests were two-sided and the level of significance was set at 5%. SPSS version 24 and R (R Core Team 2014) were used to run all statistical analyses.

Some patients had missing information on an item of the oral score questionnaire which were imputed using the multiple imputation technique since scores were not missing completely at random. Missing data can result in the loss of precision especially in evaluating the usefulness of a scale. Since incomplete data was derived from mainly one item (3. Bolus preparation/mastication) of the MBSImP scale, we decided to impute this data for completeness of the scale evaluation as all conditions were met for imputation [12, 19]. Briefly, an iterative Markov chain Monte Carlo (MCMC) method was used to impute the missing values using the fully conditional specification method in SPSS version 24. The software developed a multinomial logistic regression model by incorporating all patient characteristics and MBSImP scale items other than item 3 as predictor variables. Item 3 was considered as a dependent variable in this model and the missing values were imputed as predicted/estimated values of this variable from the above model. A total of five datasets were generated with the imputed values for the missing item, and the pooled value of that item was

used in the calculation of the total oral subscale score [12, 19].

Multivariable Cox regression models were developed for each of the feeding groups and hazard ratios with 95% confidence intervals estimated. Since combining the total MBSImP scores might mask the effect of individual subscores, separate regression models were run for the oral subscore, pharyngeal subscore and the combined score, after adjusting for gender, race, Hoehn and Yahr stages, comorbidities, the presence of depression and time to MBS since PD diagnosis. In the setting of a multivariable regression model, adjustments were made to account for differences in disease duration, H&Y stages, race, gender and time since PD diagnosis (see Table 1). Motor scores were predictably different across the three different feeding groups while a fairly proportionate number of Hoehn and Yahr stages were noted in each feeding group.

Results

Interrater reliability for the 17-item MBSImP scale showed Cohen Kappa values of $\kappa = 0.63–1$ (moderate-to-full agreement between raters) despite the difference in clinical experience.

After applying the inclusion and exclusion criteria, a total of 157 patients were eligible for this study. Patient demographical characteristics are summarised in Table 1. Patients in the group who rejected enteral feeding generally scored significantly higher on the MBSImP oral subscore, pharyngeal subscore, as well as the combined score, followed by enteral feeding group, and the oral feeding group.

The Kaplan–Meier plot for the time taken to a hospital admission for pneumonia or choking are presented for

Table 1 Distribution of demographical and clinical characteristics of the study population

Subject characteristics	Oral feeding ($n=115$)	Enteral feeding ($n=24$)	Reject enteral feeding ($n=18$)	p value
Gender, *n* (%)				0.011
Male	63 (54.7)	19 (79.1)	15 (83.3)	
Female	52 (45.3)	5 (20.9)	3 (16.7)	
Ethnicity, *n* (%)				0.649
Chinese	104 (90.4)	22 (92.0)	15 (83.3)	
Indian	3 (2.6)	1 (4.0)	2 (11.2)	
Malay	5 (4.4)	1 (4.0)	1 (5.5)	
Others	3 (2.6)	0 (0.0)	0 (0.00)	
Age at MBS, mean (SD)	76.1 (8.76)	72.8 (10.9)	73.7 (9.12)	0.212
HY stages, *n* (%)				0.080
1	1 (0.9)	1 (4.2)	0 (0.0)	
2	15 (13.4)	2 (8.3)	2 (11.1)	
2.5	16 (14.3)	0 (0.0)	2 (11.1)	
3	29 (25.9)	3 (12.5)	4 (22.2)	
4	19 (17.0)	2 (8.3)	2 (11.1)	
5	32 (28.6)	16 (66.7)	8 (44.4)	
UPDRS-III motor score (SD)	38.3 (15.9)	47.6 (21.3)	47.5 (16.9)	0.012
Disease duration at MBS, mean (SD)	7.11 (5.26)	10.2 (5.7)	7.83 (6.1)	0.39
Oral subscore, *n* (%)				0.000
Low	17 (16.5)	1 (5.0)	2 (12.0)	
Moderate	47 (40.1)	18 (75.0)	7 (38.0)	
High	50 (43.4)	5 (20.0)	9 (50.0)	
Mean (SD)	9.17 (3.31)	9.00 (1.89)	9.72 (3.99)	0.752
Pharyngeal subscore, *n* (%)				0.000
Low	30 (26.1)	1 (4.2)	0 (0)	
Moderate	53 (46.1)	5 (20.8)	2 (11.1)	
High	32 (48.3)	18 (75.0)	16 (88.9)	
Mean (SD)	6.54 (2.93)	10.5 (2.96)	11.7 (2.17)	0.000
Combined MBSImP score, mean (SD)	15.7 (4.82)	19.5 (2.71)	21.27 (4.23)	0.000

MBSImP modified barium swallow impairment scale profile, *SD* standard deviation, *MBS* modified barium swallow, *H&Y* Hoehn & Yahr, *UPDRS* Unified Parkinson's disease rating scale, *PD* Parkinson's disease, *CI* confidence interval, *HR* hazard ratio

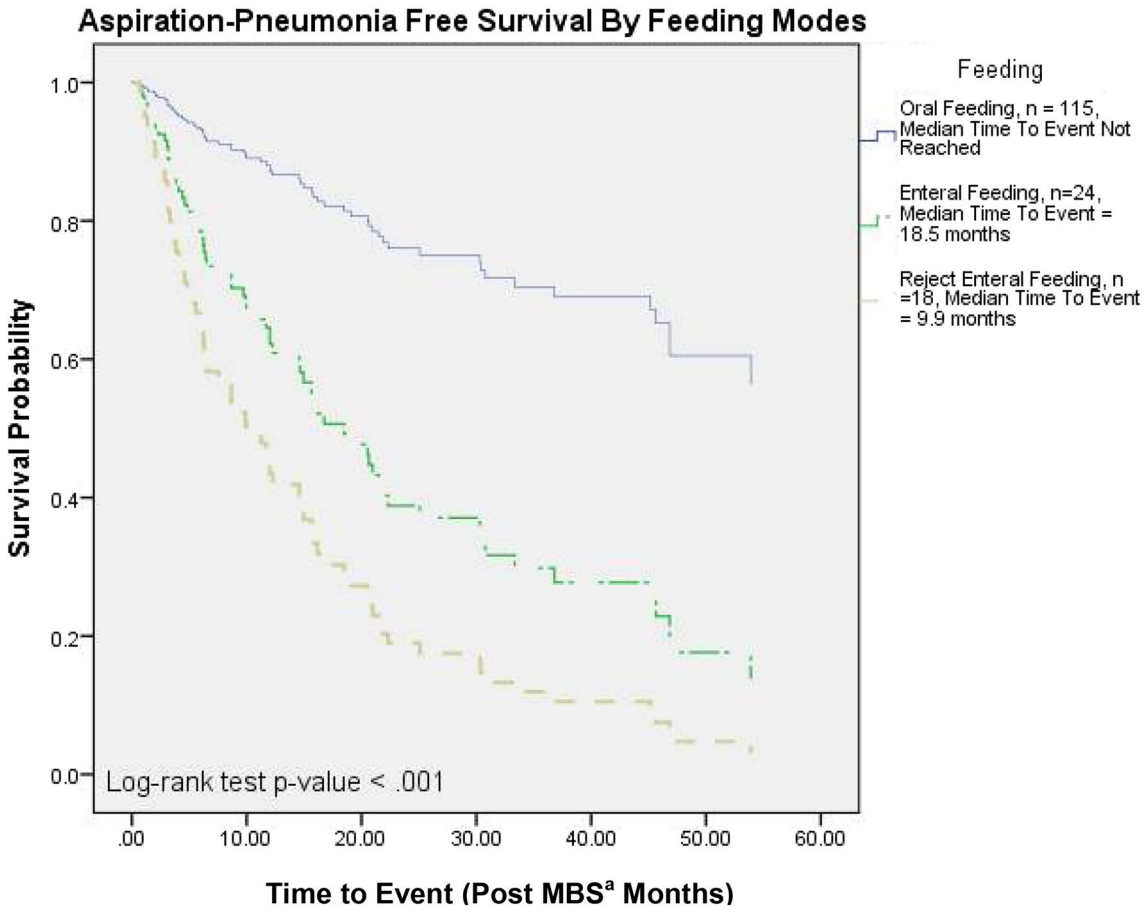

Fig. 2 Cox regression model of risk of pneumonia/choking with feeding modes

the three different feeding modes in Fig. 2, Estimates of the median time to hospitalisation for pneumonia/choking was not reached for Group A, and at 18.5 months and 9.9 months for Group B and Group C, respectively (log-rank test p value < 0.001).

For the oral feeding group, none of the MBSImP subscale scores showed any significant association with pneumonia/choking free survival (Table 2). Within the enteral feeding group, the oral subscale score was significantly associated with the outcome (HR = 2.16, 95% CI 1.19–3.90, $p = 0.011$), whereas a higher score on the pharyngeal subscale was found to be associated with prolonged survival (HR = 0.40, 95% CI 0.22–0.74, $p = 0.004$). In the group that rejected enteral feeding, both the pharyngeal subscale (HR = 3.73, 95% CI 1.09–12.77, $p = 0.036$) and the combined oral and pharyngeal subscale scores (HR = 1.63, 95% CI 1.04–2.57, $p = 0.034$) were significantly associated with poor survival. The concordance indices (C-index in Table 2) showed

Table 2 Risk of pneumonia or choking according to feeding modes and MBSImP scores

	Oral feeding	C index	Enteral feeding	C index	Rejected enteral feeding	C index
Oral total score HR (95% CI), p value	1.01 (0.91–1.11); 0.992	0.732	2.16 (1.19–3.90); 0.011	0.797	1.22 (0.81–1.84); 0.354	0.713
Pharyngeal total score HR (95% CI), p value	0.99 (0.87–1.11); 0.840	0.734	0.40 (0.22–0.74); 0.004	0.812	3.73 (1.09–12.77); 0.036	0.772
Combined score HR (95% CI), p value	0.99 (0.93–1.06), 0.918	0.733	0.94 (0.59–1.49), 0.803	0.500	1.63 (1.04–2.57), 0.034	0.782

Hazard ratios are adjusted for gender, race, HY stage, comorbidities, the presence of depression and time to MBS since PD diagnosis

MBSImP modified barium swallow impairment scale profile, *SD* standard deviation, *MBS* modified barium swallow, *H&Y* Hoehn & Yahr, *UPDRS* Unified Parkinson's disease rating scale, *PD* Parkinson's disease, *CI* confidence interval, *HR* hazard ratio

relatively fair discriminating ability (> 0.75) in predicting the observed survival in the data, indicating a fair prediction performance.

Discussion

The oral and pharyngeal subscores scores for Group B (patients on full enteral feeding) as well as the pharyngeal and combined scores for Group C (patients on full oral feeding at their own risk, after rejecting enteral feeding) were significantly associated with admission for pneumonia and choking. This shows that the subscales in the MBSImP scale may be suitable to predict a patient's risk of developing pneumonia and the risk of choking in patients who have been recommended enteral feeding.

Group C patients who rejected enteral feeding had the highest mean pharyngeal subscores which contributed to higher combined scores. These higher pharyngeal and combined scores for Group C, not only achieved significance level in its association with clinical outcomes of admission for pneumonia and choking, but also had the highest hazard ratio compared to the scores of the enteral feeding and oral feeding group. Patients who rejected enteral feeding were found to be more than 3.5 times at risk of admission for pneumonia and choking as predicted by pharyngeal scores, and 1.5 times at risk of similar clinical outcomes based on combined scores. It is possible that patients who rejected enteral feeding did so because they were asymptomatic and therefore did not experience the direct impacts of their swallowing dysfunction in relation to choking or swallowing difficulties and complaints. As mentioned in the literature, patients with PD presented with silent penetration to the cords, silent aspiration or vallecular pooling despite the absence of reported swallowing difficulties or symptoms such as coughing or choking during feeding [4, 15]. The occurrence of silent aspiration and penetration contributed to the increased risk of respiratory infection than those without [11, 17, 21].

In Group B (patients on full enteral feeding), the oral and pharyngeal scores achieved significance in its association with clinical outcomes of admission for pneumonia and choking. However, in this group, the risk for admission for pneumonia and choking as predicted by the pharyngeal subscores and combined scores was reversed, as reflected by a hazard ratio of < 1.0. When this group was compared with the group that rejected enteral feeding, the results suggested that the intervention of enteral feeding provided a protective mechanism which reduced the relative risk of admission for pneumonia and choking as predicted by pharyngeal subscores and combined scores. As the reversal of risk was not evident in the oral subscores, it suggests the dominance of the pharyngeal phase as a larger contributing factor to dysphagia in the presence of oral phase deficits.

A limitation to our study was that patients were included in the study only if they were referred for an MBS due to presenting signs of aspiration on clinical swallowing assessment, oesophageal dysfunction and/or a history of repeated admissions of pneumonia. The first MBS, which was regarded as the entry point into the study, was possibly done for patients who were at different stages of PD, with varied disease durations. However, patients with PD in early stages of the disease with no dysphagia symptoms may have high percentages of objective swallowing abnormalities [6]. Therefore, patients in the early stages of the disease with no overt dysphagia symptoms may have been left out of the study, impacting on the sample representation of the population studied. The second limitation to our study was that the order, manner and volume of consistencies presented to participants as recommended by the MBSImP protocol could not be implemented at the time of study, as our study was done retrospectively. However, there was still a standardised hospital protocol followed when conducting the MBS, which was kept consistent for all participants. This ensured that the decision-making process on starting fluid consistencies or diet textures, the feeding measures used, as well as the number of trials administered, contributed to a comprehensive swallowing study and an objective decision for recommendation of feeding mode post MBS, for the benefit of patients.

In conclusion, this is the first study investigating the MBSImP scores, as objective measures of swallowing impairment, and their association to clinical outcomes of pneumonia and choking in patients with PD. The higher scores attained on the swallow impairment profile predicted the highest risk of admission for pneumonia and choking for patients who rejected enteral feeding. This risk was reversed for the group with compliance to enteral feeding. The findings of our study suggest that the scores of the MBSImP may be suitable to predict a PD patient's risk of developing pneumonia or choking if they already have significant dysphagia requiring the need for enteral feeding, and may also serve as a reference to encourage patients' compliance to feeding recommendations post MBS.

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Compliance with Ethical Standards

Ethical approval The study was approved by the Centralized Institutional Review Board of the Singapore Health Service.

References

1. Ali GN, Wallace KL, Schwartz R, DeCarle DJ, Zagami AS, Cook IJ. Mechanisms of oral-pharyngeal dysphagia in patients with Parkinson's disease. Gastroenterology. 1996;110:383–92. https://doi.org/10.1053/gast.1996.v110.pm8566584.
2. Argolo N, Sampaio M, Pinho P, Melo A, Nobrega AC. Swallowing disorders in Parkinson's disease: impact of lingual pumping. Int J Lang Commun Disord. 2015;50(5):659–64. https://doi.org/10.1111/1460-6984.12158/1.
3. Argolo N, Sampaio M, Pinho P, Melo A, Nobrega AC. Videofluoroscopic predictors of penetration-aspiration in Parkinson's Disease patients. Dysphagia. 2015;30:751–8. https://doi.org/10.1007/s00455-015-9653-y/2.
4. Bird MR, Woodward MC, Gibson EM, Phyland DJ, Fonda D. Asymptomatic swallowing disorders in elderly patients with Parkinson's disease: a description of findings on clinical examination and videofluoroscopy in sixteen patients. Age Ageing. 1994;23:251–4. https://doi.org/10.1093/ageing/23.3.251.
5. Ellerston JK, Heller AC, Houtz DR, Kendall KA. Quantitative measures of swallowing deficits in patients with Parkinson's disease. Ann Otol Rhinol Laryngol. 2016;125(5):385–92. https://doi.org/10.1177/0003489415617774.
6. Fuh JL, Lee RC, Wang SJ, Lin CH, Wang PN, Chiang JH, Liu HC. Swallowing difficulty in Parkinson's disease. Clin Neurol Neurosurg. 1997;99:106–12. https://doi.org/10.1016/s0303-8467(97)00606-9.
7. Goh KH, Acharyya S, Ng SYE, Boo JPL, Kooi AHJ, Ng HL, Li W, Tay KW, Au WL, Tan LCS. Risk and prognostic factors for pneumonia and choking amongst Parkinson's disease patients with dysphagia. Parkinsonism Relat Disord. 2016;29:30–4. https://doi.org/10.1016/j.parkreldis.2016.05.034.
8. Han TR, Paik NJ, Park JW. Quantifying swallowing function after stroke: a functional dysphagia scale based on videofluoroscopic studies. Arch Phys Med Rehabil. 2001;82:677–82. https://doi.org/10.1053/apmr.2001.21939.
9. Kalf JG, de Swart BJ, Bloem BR, Munneke M. Prevalence of oropharyngeal dysphagia in Parkinson's disease: a meta-analysis. Parkinsonism Relat Disord. 2012;18(4):311–5. https://doi.org/10.1016/j.parkreldis.2011.11.006.
10. Kim JS, Youn J, Suh MK, Kim TE, Chin J, Park S, Cho JW. Cognitive and motor aspects of Parkinson's disease associated with dysphagia. Can J Neurol Sci. 2015;42:395–400. https://doi.org/10.1017/cjn.2015.304.
11. Lee JH, Lee KW, Kim SB, Lee SJ, Chun SM, Jung SM. The functional dysphagia scale is a useful tool for predicting aspiration pneumonia in patients with Parkinson disease. Ann Rehabil Med. 2016;40(3):440–6. https://doi.org/10.5535/arm.2016.40.3.440.
12. Liu Y, De A. Multiple imputation by fully conditional specification for dealing with missing data in a large epidemiologic study. Int J Stat Med Res. 2015;4(3):287–95. https://doi.org/10.6000/1929-6029.2015.04.03.7.
13. Martin-Harris B, Brodsky MB, Michel Y, Castell DO, Melanie S, Sandidge J, Maxwell R, Blair J. MBS measurement tool for swallow impairment—MBSImp: establishing a standard. Dysphagia. 2008;23:392–405. https://doi.org/10.1007/s00455-008-9185-9.
14. Mehanna R, Jankovic J. Respiratory problems in neurologic movement disorders. Parkinsonism Relat Disord. 2010;16(10):628–38. https://doi.org/10.1016/j.parkreldis.2010.07.004.
15. Monteiro L, Souza-Machado A, Pinho P, Sampaio M, Nobrega AC, Melo A. Swallowing impairment and pulmonary dysfunction in Parkinson's disease: the silent threats. J Neurol Sci. 2014;399(1–2):149–52. https://doi.org/10.1016/j.jns.2014.02.004.
16. Nagaya M, Kachi T, Yamada T, Igata A. Videofluorographic study of swallowing in Parkinson's Disease. Dysphagia. 1998;13:95–100. https://doi.org/10.1007/pl00009562.
17. Nobrega AC, Rodrigues B, Melo A. Is silent aspiration a risk factor for respiratory infection in Parkinson's disease patients? Parkinsonism Relat Disord. 2008;14:646–8. https://doi.org/10.1016/j.parkreldis.2007.12.007.
18. Nobrega AC, Rodrigues B, Torres AC, Scarpel RD, Neves CA, Melo A. Is drooling secondary to a swallowing disorder in patients with Parkinson's disease? Parkinsonism Relat Disord. 2008;14(3):243–5. https://doi.org/10.1016/j.parkreldis.2007.08.003.
19. Rubin DB. Multiple imputation for nonresponse in surveys. New York: Wiley; 1987.
20. Umemoto G, Tsuboi Y, Kitashima A, Furuya H, Kikuta T. Impaired food transportation in Parkinson's disease related to lingual bradykinesia. Dysphagia. 2011;26:250–5. https://doi.org/10.1007/s00455-010-9296-y.
21. Yamamoto T, Kobayashi Y, Murata M. Risk of pneumonia onset and discontinuation of oral intake following videofluorography in patients with Lewy body disease. Parkinsonism Relat Disord. 2010;16(8):503–6. https://doi.org/10.1016/j.parkreldis.2010.06.002.

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