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A comprehensive review of the diagnosis and treatment of Parkinson's disease dysphagia and aspiration

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Abstract

Bulbar dysfunction is common in Parkinson's disease (PD) with more than 80% of affected individuals developing dysphagia during the course of the disease. Symptoms can begin in the preclinical stage and individuals may remain clinically asymptomatic for years into the disease course. Furthermore, patients are not always aware of swallowing changes, which may contribute to the difference between the prevalence of self-reported dysphagia and the findings during instrumental evaluations. Dysphagia is underrecognized and contributes to the development of aspiration pneumonia which is the leading cause of death in PD. Dysphagia in PD is complex and not completely understood as both dopaminergic and non-dopaminergic pathways seem to underpin this symptom.

Areas covered: This comprehensive review will cover the epidemiology, pathophysiology, clinical evaluation, and the expert management of dysphagia and aspiration in patients with PD.

Expert Opinion: A multidisciplinary team approach is important to properly identify and to manage PD dysphagia. Regular screenings using swallowing-specific questionnaires and a clinical bedside swallow evaluation (CSE) along with objective instrumental assessments using videofluoroscopic swallow study (VFSS) or fiberoptic endoscopic evaluation (FEES) are necessary for the detection of dysphagia. Future studies are needed to better understand the mechanism(s) involved in PD dysphagia, establish markers for early detection and progression, and develop evidence-based treatment options.

Keywords

aspiration; dysphagia; evaluation; management; Parkinson's disease; pathophysiology; swallowing; treatment

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1. Introduction

Parkinson's disease (PD) is one of the most common neurological disorders and is characterized by motor symptoms including tremor, rigidity, bradykinesia, and postural instability. Dysphagia is a significant problem in PD and swallowing has been reported to affect morbidity and mortality (1). Current reports estimate that 30% to greater than 80% of patients with PD will develop dysphagia during the course of their disease (2,3). The development of dysphagia contributes to the risk of aspiration pneumonia, which is the leading cause of death in this population (4,5). If an aspiration event occurs, the risk of developing aspiration pneumonia depends on the type and volume of material aspirated, bacterial load of aspirated material, and the individual's response to aspiration such as cough, mucociliary action of the lungs, and immune response (6). In addition to swallowing dysfunction, factors that increase the risk for aspiration pneumonia include a compromised immune system, respiratory dysfunction, poor oral hygiene, poor functional status, polypharmacy, and enteral feeding (7–10). Furthermore, dysphagia can have a significant impact on PD related quality of life specifically social interactions, fatigue, and the ability to maintain a reasonable body weight (11–15).

Often swallowing dysfunction goes unrecognized in early PD. Dysphagia can occur during any stage of the disease including preclinical or prodromal stages (16,17). Clinical predictors of PD dysphagia include Hoehn and Yahr greater than 3 (advanced PD), dementia, anterior spillage of food and/or liquid from oral cavity (i.e. drooling), weight loss, or a Body Mass Index of <20 kg/m^2(18–21). Patients with PD can have impaired swallowing safety and efficiency across the 3 stages of swallowing: oral, pharyngeal, and esophageal; however the pathologic mechanisms remain somewhat unclear (22). Early detection, assessment, and management of dysphagia in patients with PD by a multidisciplinary team can improve swallowing safety and efficiency, quality of life, nutrition, and hydration (23–29).

1.1 Definition

The stages of swallowing include oral, pharyngeal, and esophageal. Oral phase is defined by mastication and tongue movements that propel the bolus to the pharynx. The pharyngeal phase consists of moving the bolus through the pharynx, which includes closure of the laryngeal vestibule and glottis, pharyngeal peristalsis, and relaxation of the upper esophageal sphincter. The esophageal phase includes contraction of the upper esophageal sphincter, esophageal peristalsis, and relaxation of the lower esophageal sphincter resulting in the transport of the bolus into the stomach (30).

Swallow safety describes how well an individual is able to protect their airway during the act of swallowing. Impaired swallow safety includes penetration and aspiration. Penetration is defined by material entering the airway above or to the level of the vocal folds. Aspiration occurs when material enters the airway below the level of the true vocal folds. *Swallow efficiency* describes the individual's ability to move the material (i.e. bolus) from the oral cavity through the pharynx and esophagus. Impaired swallow efficiency includes residue within the oral cavity, pharynx, or esophagus.

1.2 Epidemiology

One meta-analysis reported a worldwide prevalence of PD that was increasing with age from 41 per 100,000 in subjects 40–49 years old to approximately 1900 per 100,000 in subjects over 80 years of age (31). Estimates have revealed that by the year 2030, approximately 9 million people globally will be diagnosed with PD (11). This has been referred to as a PD pandemic (32).

The reported prevalence of dysphagia in patients with PD varies widely. This is likely due to the mismatch between patient reported swallowing difficulties and findings during instrumental evaluations. Another meta-analysis revealed the prevalence of dysphagia based on patient reports was 35%, whereas in objective clinician rated measurements it increased to 82% (2). Pflug et al. (2018) found more than 50% of patients who did not report swallowing dysfunction were confirmed to have dysphagia using flexible endoscopic evaluation of swallowing (FEES) (33).

For most patients with PD, dysphagia is present during advanced stages, on average 10–15 years after symptom onset (21,34). The rate of clinical dysphagia increases after 15 years from the onset of PD symptoms (11). Aspiration pneumonia is the most common cause for hospitalization in patients with PD with a disease duration of more than 5 years (35). Additionally, the majority of these patients had abnormal videofluoroscopic swallow study/modified barium swallow study (VFSS/MBSS) findings, cognitive impairment, and a history of psychiatric symptoms (36). Predictors of patients with PD developing aspiration pneumonia include impaired mastication, poor lingual motility prior to transfer, aspiration, and increased total swallow time (37).

1.3 Neural control of swallowing

All phases of swallowing have distinct neural control mechanisms that include sensory and motor integration by cortical and subcortical structures (24). Swallowing is a complex behavior that involves a highly coordinated sensorimotor sequence consisting of the activation and suppression of more than 30 muscles bilaterally (38).

The oral phase of the swallow is considered predominately volitional, while pharyngeal and esophageal phases are involuntary. The cranial nerves involved include the trigeminal (V), facial (VII), glossopharyngeal (IX), vagus (X), accessory (XI), and hypoglossal (XII). Information is relayed to the brainstem, with afferent pathways to the bilateral prefrontal, frontal, and parietal cortices (39). The efferent pathways from the cortex to the brainstem motor nuclei are modulated by the cerebellum. The upper pharynx and the esophagus are controlled by the vagus nerve (40).

The central pattern generator for swallowing (CPGs) produces the coordinated sequential motor events required (41,42). CPGs areas exist bilaterally in the dorsomedial and ventrolateral medulla oblongata (43,44). In the dorsomedial medulla, the generator neurons involved in the triggering, shaping, and timing of the sequential or rhythmic swallow pattern reside within the nucleus tractus solitarii. In the ventrolateral medulla, the switching neurons are involved in distributing incoming sensory information regarding bolus size, taste, location, and viscosity to the appropriate motor nuclei, including the trigeminal

nucleus, facial nucleus, nucleus ambiguous, and hypoglossal nucleus (45,46). There is also supramedullary modulation of the CPGs from cortical and subcortical areas (42,43).

2. Pathophysiology

The cardinal symptoms of PD include tremor, rigidity, bradykinesia, and postural instability which are associated with a gradual loss of dopaminergic neurons in the substantia nigra, and deposition of alpha-synuclein across many motor and non-motor circuitries (47). The pathophysiology of dysphagia in PD is not fully understood, however the disturbance of dopaminergic and non-dopaminergic mechanisms, brainstem dysfunction, and muscle atrophy are likely contributing factors (48). The specific circuitry within the basal ganglia systems has been elusive, but there is agreement that it must include more than the typical dopaminergic loss. Studies have shown basal ganglia dysfunction caused by degeneration of dopaminergic neurons in the substantia nigra likely plays an important role (11,49,50). Lewy bodies (alpha-synuclein aggregates) are deposited in various non-dopaminergic cortical areas and in the brainstem, including the CPGs in the medulla, which can impair the sequential swallowing pattern (21).

Chronic denervation and reinnervation secondary to neurodegeneration associated with PD can lead to atrophy of the muscles which are utilized during the pharyngeal phase of swallowing (51,52). Research has identified possible associated changes in the morphology of pharyngeal muscle fibers and changes in enzymatic activity (28,39). Alpha-synuclein in peripheral nerves innervating the pharyngeal muscles has been found in patients with PD exhibiting dysphagia (53). Bradykinesia and rigidity can contribute to delayed onset of the oropharyngeal phase of swallowing and impaired cricopharyngeal opening (54–56). There is increasing evidence that alpha-synuclein accumulation occurs outside of the central nervous system, such as the enteric nervous system, likely contributing to the observed esophageal impairments (57,58). It is unclear which changes are biological and which may account for swallowing dysfunction (59).

Patients with PD can experience difficulty during any or all stages of swallowing (Table 1). It is important to note that normal variation in swallowing and age-related swallowing changes (presbyphagia) exist and should not be labeled as dysphagia (60–64).

3. Swallowing impairments in PD

3.1 Oral phase

Oral phase deficits include tongue pumping/rocking (a repetitive, rocking, non-propulsive movement of the tongue), impaired bolus formation resulting in the presence of oral residue, piecemeal deglutition, and/or anterior spillage due to reduced lip closure (65–67). Reduced tongue strength and pressure generation between the tongue and the palate have been found in subjects with PD compared to healthy controls (68). Subjects with PD who exhibit dysphagia on VFSS (aspiration and/or moderate amounts of residue in the oral cavity) were found to have reduced maximum tongue pressure, particularly at the anterior part of the tongue, compared to non-dysphagic PD subjects (69). However, Fukuoka et al. (2018) found no significant difference in maximum tongue pressures between PD subjects with and

without dysphagia. Their study revealed PD subjects with dysphagia exhibited prolonged duration of tongue pressure, increased time to peak pressure, and reduced pressure gradient compared to the PD subjects without dysphagia (70).

3.2 Pharyngeal phase

Pharyngeal phase deficits include delayed initiation of the pharyngeal phase of swallowing, reduced hyolaryngeal excursion, reduced base of tongue retraction, reduced pharyngeal constriction (creating variable swallowing pressures), delayed airway closure, reduced duration of airway closure, and decreased pharyngeal/laryngeal sensitivity (16,71,72). Overall, these deficits can result in aspiration or pharyngeal residue. A recent retrospective analysis of patients with PD during VFSS revealed predictors of penetration and aspiration included reduced hyolaryngeal excursion, delayed initiation of the pharyngeal swallow, and increased volume of liquid bolus (73). Studies have reported diminished or absent cough behaviors in patients with PD, particularly in those with dysphagia, which poses a risk for uncompensated aspiration (i.e. material entering the airway with an inappropriate response to expel the material) (12,74,75). Discoordination of breathing and swallowing has also been found in patients with PD. Inhalation versus typical exhalation after swallowing may reduce swallow safety (76). Additionally, a recent study of 20 patients with PD revealed lower saliva Substance P concentrations in individuals with mild pharyngeal dysphagia compared to individuals without dysphagia (77). Substance P is a neuropeptide involved in the regulation of the response by the pharyngeal mucosa to stimuli (77–80).

3.3 Esophageal phase

Esophageal phase deficits include impaired peristalsis, incomplete bolus transit, repetitive contractions, and inconsistent findings of reduced opening duration and/or extent of the upper esophageal sphincter (UES) (25,28,81,82). Sung et al. (2010) completed pharyngoesophageal manometry on subjects with early-stage PD and found reduced UES resting pressure compared to age-matched healthy controls (16). Abnormal esophageal manometry results were found in 40.7% of subjects for liquids and 57.4% of subjects for viscous material (16). Suttrup et al. (2016) analyzed oropharyngeal dysphagia with FEES and esophageal swallowing using high-resolution manometry (HRM) in 65 subjects with PD across disease severity. The study revealed major esophageal disorders in nearly 1/3 of subjects and minor impairments in 95% of subjects. Impairments observed were esophageal dysmotility, and increased intrabolus pressure with advanced disease. No association between FEES and esophageal HRM were found (28).

4. Evaluation

During the initial stages of PD, dysphagia is frequently unrecognized. Use of subjective in addition to objective measures are required to accurately detect the presence of dysphagia. Screening for dysphagia may include swallowing-specific questionnaires, CSE, and/or water tests. A baseline instrumental evaluation is still recommended to assess oropharyngeal swallowing safety and efficiency, and to allow for a comparison of oropharyngeal swallow function as the disease progresses. Instrumental evaluations such as VFSS/MBSS and FEES are considered to be the gold standard for the evaluation of *oropharyngeal* dysphagia

(11,33,83). Moreover, these studies provide vital information for the management of dysphagia by analyzing the effects of bolus volume, bolus consistency (liquids, pudding/puree, solids, and pills), swallow timing, response (i.e. cough, throat clearing), effectiveness of the response to penetration/aspiration, material and/or residue clearance, and impact of compensatory strategies.

4.1 Swallowing-specific questionnaires

Swallowing-specific questionnaires such as the Swallowing Quality of Life questionnaire (SWAL-QOL) or Eating Assessment Tool (EAT-10) can help identify patients at risk for swallowing dysfunction (84–87). The PILL-5 is a self-reported validated questionnaire for pill dysphagia (88). There are PD-specific swallowing questionnaires that are validated including the Swallowing Disturbance Questionnaire (SDQ) and Munich Dysphagia test-Parkinson's disease (MDT-PD) (19,89). Buhmann et al. (2019) found the MDT-PD questionnaire did not reliably detect aspiration in patients with PD and concluded that the questionnaire should not be solely used as a screening tool for dysphagia (90).

4.2 Clinical bedside swallow evaluation (CSE)

A clinical bedside swallow evaluation (CSE) performed by a speech-language pathologist or logopedic can help identify patients who need additional testing. The CSE includes: review of past medical history, examination of cranial nerves and cognition, and signs of dysphagia during oral trials (including labial spillage, oral residue/pocketing, mastication efficiency, vocal quality, presence of cough, or throat clearing) (91–93). Additionally a modified water test can be performed to determine maximum swallow volume or maximum swallowing speed to identify individuals with PD dysphagia (11,34,94–98). Of note, the water test is not a validated tool, and may underestimate the severity of dysphagia.

4.3 Video fluoroscopic swallow study (VFSS)/modified barium swallow study (MBSS)

A VFSS/MBSS is completed by a speech-language pathologist and a physician (most commonly a radiologist) to assess the *oral and pharyngeal* phases of the swallow. It consists of a radiographic video taken place in the lateral view, at a minimum of 30 frames per second (99,100). The patient is seated in a chair and swallows varying consistencies of barium. In the lateral view, the following can be assessed: mastication, bolus containment, bolus formation, bolus transport, tongue pumping, oral residue, soft palate elevation/retraction, base of tongue retraction, hyolaryngeal excursion, epiglottic inversion, laryngeal vestibule closure, quantification of penetration or aspiration (timing, depth, estimated volume, patient response), pharyngeal contraction (also known as pharyngeal stripping wave), pharyngeal residue, and upper esophageal opening extent and duration (101). It also provides a view of the proximal esophagus to assess esophageal clearance (101). An anterior-posterior (A-P) view can be obtained to assess pharyngeal constriction symmetry, bolus flow, and scan for esophageal clearance in an upright position (101). Images captured from the A-P angle can help determine if additional evaluations by gastroenterology are necessary to assess the esophageal stage of the swallow.

4.4 Fiberoptic endoscopic evaluation of swallowing (FEES)

FEES is completed by trained physicians (ENTs, phoneticians, or neurologists) or speech-language pathologists to assess the *pharyngeal* phase of the swallow while the patient consumes varying consistencies of liquids and/or solids as well as pills (83). This evaluation is more invasive than VFSS and involves passing an endoscope through the nose into the oropharynx to visualize the base of the tongue, pharynx, larynx, and part of the trachea. It is taken from a superior (rostral to caudal) viewpoint. FEES can be completed at the bedside and can assess secretion management along with structural changes, which are not possible with VFSS. Additional advantages include the absence of radiation exposure, ease of frequent follow-up examination (if needed), flexibility with patient positioning, sensory testing (FEESST), visualization of vocal cord mobility, and biofeedback (102). During the FEES, a “white out” period due to the reflection of light from the endoscope against structures prohibits the visualization of anatomy and bolus flow during the height of the swallow. This could translate into missing penetration or aspiration.

Interpretation of the instrumental evaluations can be variable amongst professionals. The Penetration-Aspiration Scale (PAS) is an 8-point scale commonly used to quantify the severity of airway invasion during swallowing (103). Scales to quantify residue using VFSS include the Normalized Residue Ratio Scale (104), the Vallecular Residue Ratio Scale (105), and the Bolus Residue Scale (106). When evaluating with FEES, the Yale Pharyngeal Residue Severity Rating Scale can be utilized (107). Additionally the MBS Impairment tool (MBSImP™) developed by Martin-Harris and colleagues (108) is a standardized approach to evaluate VFSS by a trained speech-language pathologist who follows a protocol to rate seventeen components of swallowing physiology and bolus flow measures.

4.5 High Resolution Manometry (HRM)

HRM can be used to assess pharyngeal or esophageal contraction in patients with PD (28,52,82). During this procedure a small catheter is passed through the nose into the pharynx and esophagus in order to measure pressures generated along the pathway.

4.6 Other swallowing evaluation modalities

Other modalities have been utilized in research studies to assess dysphagia including surface EMG or ultrasonography (US) (109–112) as well as previously mentioned tongue strength assessments (68,70).

5. Management of dysphagia in individuals with PD

A multidisciplinary team approach for the evaluation and management of dysphagia to prevent significant consequences of dysphagia such as malnutrition, dehydration, aspiration pneumonia, or choking, which could result in death, is critical for optimal care in PD (113). Weight monitoring and nutritional evaluations should be implemented early to reduce the likelihood of malnutrition and dehydration. Also, given the occurrence of subclinical dysphagia and silent aspiration, it is important to counsel patients on signs and symptoms of swallowing difficulties. Dysphagia management varies based on the underlying deficits noted during the instrumental evaluation. Treatment approaches to improve swallow safety

and efficiency can be divided into compensatory behavioral strategies, dietary modifications, or rehabilitative exercises.

5.1 Compensatory behavioral strategies

Compensatory strategies to improve swallow safety and efficiency are prescribed by a speech-language pathologist or logopedic. Examples include: smaller bites/sips, larger sips, alternating bites and sips, pacing, varying head positions, swallowing twice per bite/sip, or pills taken with pureed consistency (ie: apple sauce or pudding) (48,114–116). For example, smaller sips may be used to reduce aspiration while larger sips can increase sensory input to improve oral and pharyngeal swallow initiation, increase pharyngeal pressure generation, and/or provide weight to assist with passive inversion of the epiglottis to help with laryngeal vestibule closure (73,117–120). Additionally, impulsive feeding exhibited by some individuals with PD can result in food collection in the oral cavity, increasing the risk of aspiration and choking (114). Reducing distractions and dual-tasking for patients with cognitive and attention deficits during meals can increase swallow safety (121). A speech-language pathologist may suggest pacing strategies or adaptive equipment to limit the size of each bite or sip. Timing meals, in the context of achieving the maximal benefit of levodopa therapy, could facilitate improved upper extremity control for feeding during mealtime (114,122).

5.2 Dietary modifications

Results from instrumental evaluations are used to determine the least restrictive, but safest diet for patients with PD. Dietary modifications may include changing the viscosity of liquids by using an artificial thickener, chopped, or pureed food (73,120,123). Foods of high viscosity may be difficult for patients with reduced tongue base retraction and pharyngeal constriction to efficiently swallow (114,119). There is also evidence that increasing sensory input with sour or cold foods could help trigger the oral and pharyngeal swallow (119,124–127). Patients given a modified diet should receive skilled speech-language therapy in an attempt to rehabilitate their swallow function and upgrade their diet. Diet modifications can have a significant impact on a patient’s quality of life, thus repeated instrumental evaluations are encouraged to evaluate for an improvement in swallowing that safely allows for a diet upgrade.

The Frazier Free Water Protocol may be appropriate for patients on modified diets identified to be at risk for aspirating thin liquids (128,129). This protocol allows patients to consume water in a structured manner, and is associated with improvements in fluid intake, oral health, quality of life, compliance with dietary restrictions for dysphagia management and xerostomia.

In advanced PD, a feeding tube may be considered for short or long-term use if a patient demonstrates an unsafe swallow, inability to consume pills or maintain adequate hydration or nutrition despite using available techniques. As part of providing patient-centered care, patients and their families should be educated regarding the risk of unsafe swallowing and nutrition/hydration, along with the risks/benefits of a feeding tube. A feeding tube may reduce, but does not eliminate, the risk of aspiration or aspiration pneumonia, as aspiration

can still occur due to reflux or saliva (130–134). At times, patients with severe dysphagia choose to consume liquids or solids by mouth for pleasure. These patients can receive their vital nutrition and hydration by an enteral tube. Ultimately, the decision made by the patient or their healthcare proxy should be documented and their wishes should be followed as they have the right to refuse life-sustaining treatment (135). In this case, treatment will include decreasing aspiration risk as much as possible, patient comfort, and quality of life.

5.3 Rehabilitative strategies

Many patients with PD dysphagia will benefit from rehabilitative techniques including exercises prescribed to strengthen the expiratory muscles (136–138). Troche and colleagues (2010) have shown Level 1 evidence supporting the use of expiratory muscle strength training (EMST) to improve airway protection in PD (139). The application of EMST consists of a forceful exhale into a pressure threshold device which opens a valve depending on the pressure generated (140). The device maintains a constant pressure load against exhalation, and this improves respiratory muscle strength (141). The training protocol involves completing 5 sets of 5 successful repetitions, 5 days/week for at least 4 weeks (139). The device is periodically reset as the patient gets stronger. EMST at 75% of a participant's average maximum expiratory pressure was found to improve hyolaryngeal function, PAS during VFSS, and voluntary cough effectiveness (139,142). Wheeler et al. (2008) found EMST may strengthen the suprahyoid muscles using surface EMG. These muscles aid in hyolaryngeal elevation and laryngeal vestibule closure for improved airway protection (143).

The Lee Silverman Voice Treatment (LSVT®) is an exercise based behavioral treatment program for speech symptoms of PD (e.g. hypokinetic dysarthria) (144–146). While LSVT® is mainly used to target speech, research has shown positive benefits on swallowing for a subset of patients (147,148). Its effects on swallowing include improvement in tongue base function and bolus control during the oropharyngeal swallow, along with reduced oral transit time and oral residue, and increase upper esophageal sphincter opening extent and duration (147,148).

Additional exercises may include effortful swallow, Mendelsohn maneuver, or falsetto exercises. For an effortful swallow, patients are encouraged to squeeze hard with their muscles when swallowing, promoting posterior tongue movement for bolus clearance. This exercise can be combined with surface EMG to provide biofeedback (149,150). Adequate effortful swallow exercises have demonstrated increased duration of hyolaryngeal excursion, laryngeal vestibule closure, and upper esophageal sphincter opening (151,152). The Mendelsohn maneuver can also improve laryngeal excursion (152–155). This maneuver requires the patient to hold their larynx in an elevated position (at the highest point) for 2–3 seconds at the height of the swallow to facilitate opening of the esophagus (154). During falsetto exercises, an individual is asked to slide their voice up to a high pitch and sustain it for several seconds to improve hyolaryngeal elevation (156,157).

Another tool available to speech-language pathologists is neuromuscular electrical stimulation (NMES or e-stim) which uses surface electrodes to deliver an electrical current to peripheral nerves to cause muscle contraction. It is typically used in addition to voluntary

exercise, however there is insufficient evidence to show its impact on dysphagia (158–160). The majority of studies on NMES and dysphagia have been completed in the stroke population. Park et al. (2018) evaluated the use of NMES (placed in the infrahyoid region) vs sham stimulation combined with an effortful swallow in 18 patients with PD. Participants underwent five, 30-minute sessions per week for 4 weeks (161). They found a difference in the PAS scores and increased hyoid movement in the experimental group compared to the placebo group, however there was no significant change in the oral or pharyngeal phase on the Videofluoroscopic Dysphagia Scale (161).

5.4 Additional considerations

Xerostomia (subjective dry mouth or hyposalivation) can also be a symptom of PD due to autonomic dysfunction or a medication side-effect, and can have a profound impact on swallowing (162–164). Strategies to improve this symptom can include throat lozenges, synthetic saliva, or frequent sips of water.

Another non-motor symptom commonly encountered is sialorrhea (drooling or excessive salivation). Sialorrhea appears to be related to reduced frequency of spontaneously swallowing saliva rather than an overproduction of saliva (165). It can result in the inability to maintain saliva in the oral cavity. Non-pharmacologic management strategies include wiping with a cloth, encouraging an upright posture, and frequent reminders to swallow. Off-label use of anticholinergics to reduce salivary secretions may be considered, however there is insufficient data regarding its safety (166). Commonly used anticholinergics include glycopyrrolate and sublingual atropine drops. The most effective intervention for drooling is local injections with botulinum toxin serotypes A or B to the parotid and/or submandibular glands (167–171). Currently incobotulinumtoxinA (Xeomin®) and rimabotulinumtoxinB (Myobloc®) are the only approved botulinum toxins for sialorrhea (172,173). A marked reduction in oral secretions can lead to dental caries, thus these strategies should be implemented with caution.

Patients with PD are at an increased risk for reduced oral health due to difficulty executing routine oral care secondary to motor symptoms, xerostomia, dysphagia, and/or drooling (174–178). Poor oral health can increase the risk of dental caries, periodontal disease, and tooth loss (179). It also strongly correlated with an increased risk of developing aspiration pneumonia (180). Interestingly, one study found that only 38% of known aspirators (with varying medical conditions) developed pneumonia stating "…dysphagia and aspiration are necessary, but not sufficient conditions for development of pneumonia. Other risk factors must be present as well" (7). Research has shown a reduction of pneumonia in nursing home residents receiving oral care (8,181–183). In fact, Bassim et al. (2008) found nursing home residents who did not receive oral care were three times more likely to die from pneumonia than those who received oral care after adjusting for other risk factors causing pneumonia (183). Therefore, routine oral care is critical in optimal management of dysphagia and the prevention of aspiration pneumonia. Oral care should be completed regardless of dental status (natural teeth, dentures, or edentulous) or feeding status (oral or enteral). It is recommended oral care be completed at a minimum of 2x/day with regular dental appointments at least every 6 months.

At this time, there is inconclusive evidence that swallowing improves with levodopa therapy (184–186). Studies completed have included a small sample size, patients in “On”, “Off”, or incomplete On/Off states, have been open-label studies, or used varying methods of dysphagia diagnosis for patient enrollment and outcome measurements of dysphagia. Rigidity and bradykinesia may affect the oral phase of swallowing, thus it could be impacted by dopaminergic medications (187,188). Occasionally some individuals will report an improvement after medication adjustment (14). Additionally, no significant differences in swallowing dysfunction have been observed in patients with dyskinesia compared to those without (189).

Deep brain stimulation (DBS) therapy of the subthalamic nucleus (STN) or the globus pallidus internus (GPi) is another option for treating motor symptoms in PD, but it has not resulted in clinically significant improvement in swallowing when comparing “On” and “Off” stimulation states (48,190). Troche et al. (2014) indicated that STN DBS may be associated with increased swallowing dysfunction compared to GPi DBS, at least with unilateral lead placement, however a head to head randomized comparison has not been performed (191). Low frequency stimulation (60Hz) compared to high frequency (130Hz) STN-DBS revealed a decrease in aspiration frequency by 57% and reduced swallowing difficulty by 80% (192). In patients who can tolerate low frequency DBS, this may be an approach favorable to swallowing, although it does not affect tremor and other motor symptoms as effectively as high frequency stimulation. At this time, the evidence regarding DBS and swallowing outcomes remains inconclusive.

6. Conclusion

The majority of patients with PD will experience dysphagia during the course of their disease, however clinical diagnosis remains a challenge especially in detecting subclinical dysphagia. Decreased patient awareness of bulbar dysfunction can result in delayed evaluation and management, as well as serious health concerns associated with aspiration pneumonia. At this time, the pathophysiology of dysphagia in PD is not fully understood, however disturbance of dopaminergic and non-dopaminergic mechanisms, brainstem dysfunction, and muscle atrophy are likely contributing factors (193). PD dysphagia does not respond to conventional treatments used for motor symptoms such as dopaminergic medications or DBS. Early and ongoing assessments by a multidisciplinary team using swallowing specific questionnaires, CSE, and instrumental evaluations are critical for identification of PD dysphagia. Management of PD dysphagia includes compensatory strategies, diet modifications, and/or rehabilitative exercises to improve quality of life and reduce the risk of morbidity and mortality. Additional research is needed to better understand the pathologic mechanisms underlying PD dysphagia and to optimize treatment outcomes.

7. Expert Opinion

This article presents the current knowledge, diagnostic evaluation, and management options for PD dysphagia and aspiration. As the number of individuals with PD rise, PD dysphagia will continue to be a symptom in need of early identification and novel treatment options. A

multidisciplinary team approach including a speech-language pathologist, physicians (ENT, phonetician, movement disorder trained neurologist), nutritionist, and occupational therapist is important to properly identify and manage PD dysphagia. Regular screenings using subjective swallowing specific questionnaires and a clinical bedside swallow evaluation, in addition to objective instrumental evaluations (videofluoroscopic swallow study or fiberoptic endoscopic evaluation of swallowing) are necessary for detection of dysphagia. Dysphagia in PD impacts quality of life, social participation, fatigue, nutrition, hydration, morbidity, and mortality, and is likely a contributing factor in the development of aspiration pneumonia, which is the leading cause of death in this patient population.

A comprehensive understanding of why aspiration pneumonia occurs in a disproportionately high rate in PD is needed. Ongoing investigations to better understand the mechanism(s) of PD dysphagia and the impact of alpha-synuclein in both the central and peripheral nervous systems is warranted. Limited information is known about the neural networks involved in swallowing including the inhibitory and excitatory pathways (42). Additionally, supramedullary influences on swallowing need additional investigation. These findings could potentially elucidate the underlying pathologic mechanism of various causes of dysphagia. A recent pilot study revealed reduced saliva concentrations of substance P, a neuropeptide that is involved in the swallowing reflex, in PD patients with early pharyngeal dysphagia (77). Although this observation needs deeper investigation, agents increasing substance P may be targets for future studies.

The development of a marker for the early detection and progression of dysphagia will allow for earlier implementation of rehabilitative strategies aimed to maintain safe swallowing function, nutrition, and hydration. The current gold standard for identification of dysphagia is VFSS or FEES. Current management of dysphagia varies based on the underlying deficits noted during the instrumental evaluation.

Treatment approaches can be divided into compensatory behavioral strategies, dietary modifications, or rehabilitative exercises, which are prescribed by a speech-language pathologist or logopedic. Many of the current management methods for dysphagia are effective but may be cost prohibitive for some patients as it requires frequent therapy sessions with repeated instrumental evaluations. Frequent visits also pose an additional challenge given the mobility issues patients with PD often face. Current research is developing portable monitoring devices to collect biofeedback data in real-time during swallowing and swallowing exercises. Previous portable devices have been limited by ergonomics when placed on the skin in the submental area, which effects data quality and patient comfort. Using recent advances in electronics, researchers have developed flexible wearable technology to mitigate these issues. A flexible sensor sticker is placed on the patient’s submental area and is connected to a small wireless transmitter worn on the patient’s shirt. Muscle activity during swallowing is recorded and wirelessly transmitted to software, which is then analysed by a speech-language pathologist or physician. These devices are reported to be more comfortable, cost-effective, and can be used about 10 times before disposing (194). Furthermore, the increasing use of telemedicine and the ease of data transmission to a secure server can allow their speech-language pathologist to remotely monitor their therapy progress.

Lastly, it is important to emphasize that the presence of aspiration *alone* does not cause aspiration pneumonia, and typically additional factors such as a compromised immune system, respiratory dysfunction, poor oral hygiene or functional status, polypharmacy, or enteral nutrition are associated with developing aspiration pneumonia (7,8,195,196). A comprehensive evaluation of not only swallowing function, but also cough, oral hygiene, and general activity level is critical to managing dysphagia in patients with PD.

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Article Highlights:

- More than 80% of patients with PD develop dysphagia during the course of their disease, and it may occur even in pre-symptomatic stages.
- PD dysphagia is associated with aspiration pneumonia, which is the most frequent cause of PD related death.
- Routine screening for dysphagia with swallowing-specific questionnaires and/or clinical bedside swallow evaluation, ***as well as*** formal instrumental evaluations utilizing either videofluoroscopic swallow study (also known as modified barium swallow study) or fiberoptic endoscopic evaluation of swallowing are necessary for detection of dysphagia.
- Management of dysphagia includes compensatory strategies (i.e. postural changes, pacing of bites and sips, bolus volume, etc.), diet modifications, and exercises aimed to strengthen muscles, improve airway safety, and swallow efficiency.
- Clinical predictors of dysphagia in patients with PD include Hoehn and Yahr greater than 3 (advanced PD), dementia, anterior spillage of food and/or liquid from oral cavity (i.e. drooling), weight loss, and a Body Mass Index of $<20\ kg/m^2$.
- There is one randomized clinical study revealing that expiratory muscle strength training (EMST) may be helpful in prevention of aspiration in PD.
- Early detection and management of dysphagia in patients with PD through the use of a multidisciplinary team can improve quality of life, swallowing safety and efficiency, nutrition, and hydration.

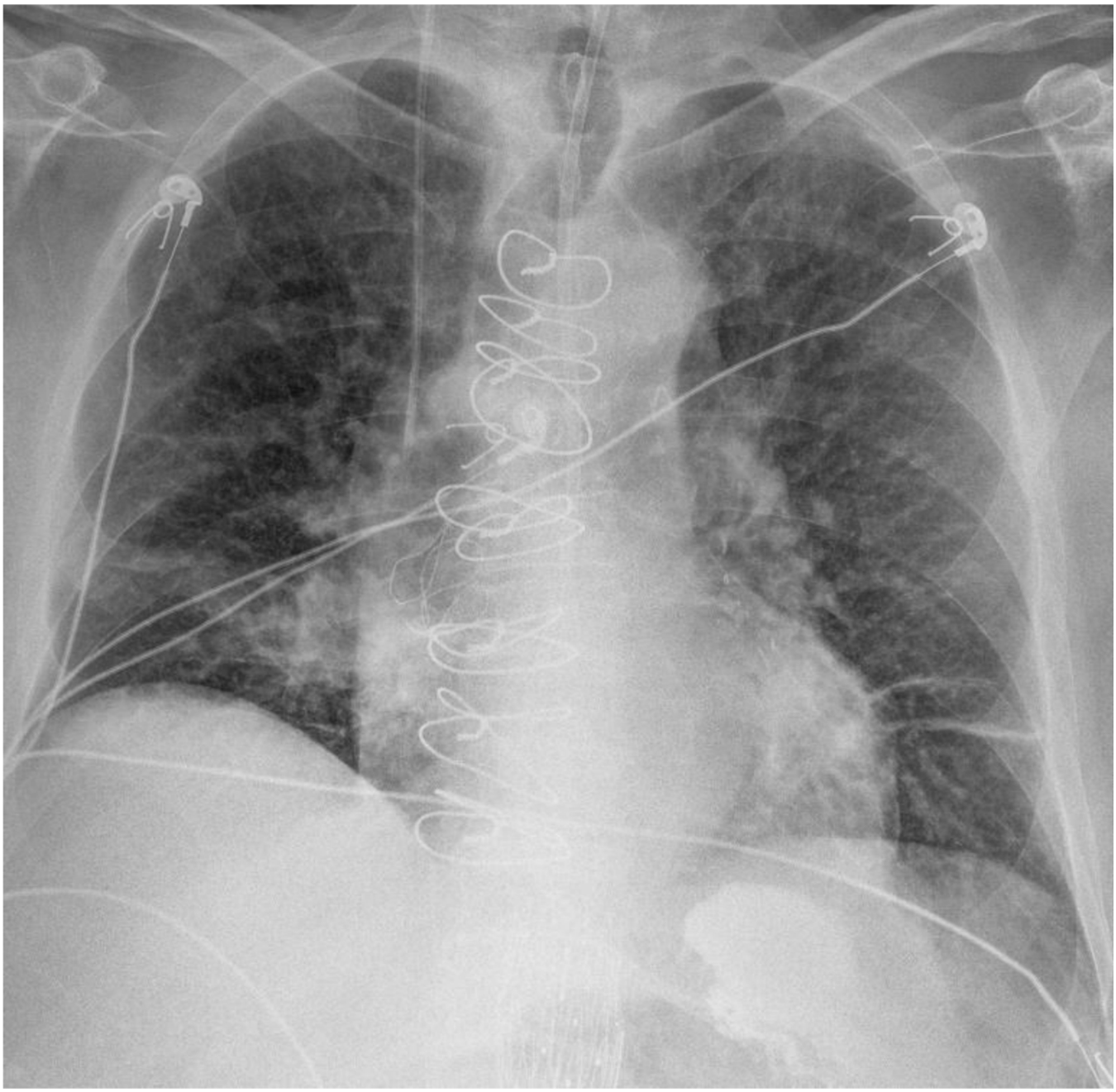

Figure 1.
Chest radiograph with features of aspiration pneumonia. This image shows classic right lobar consolidation typically seen in aspiration. Electrocardiogram leads and suture wires from a previous sternotomy are also seen.

Figure 2.
Mobile C-Arm Fluoroscopy machine. The patient sits in a chair while a VFSS is conducted to evaluate oropharyngeal dysphagia.

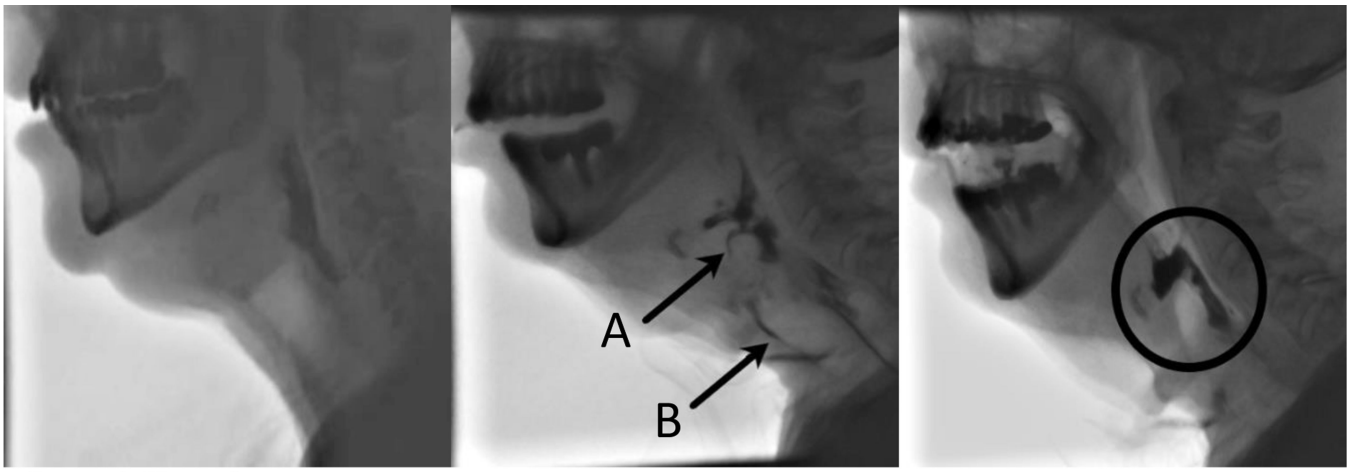

Figure 3.

Videofluoroscopic swallow study (VFSS). *Image 1*: Normal swallow with thin liquid with complete laryngeal vestibule closure. *Image 2:* Reduced swallow safety with thin liquid indicated by aspiration along the anterior tracheal wall (A) and penetration into the laryngeal vestibule above the level of the vocal folds (B). *Image 3:* Reduced swallow efficiency with solid consistency with marked residue seen in the valleculae, and aryepiglottic folds into the pyriform sinuses.

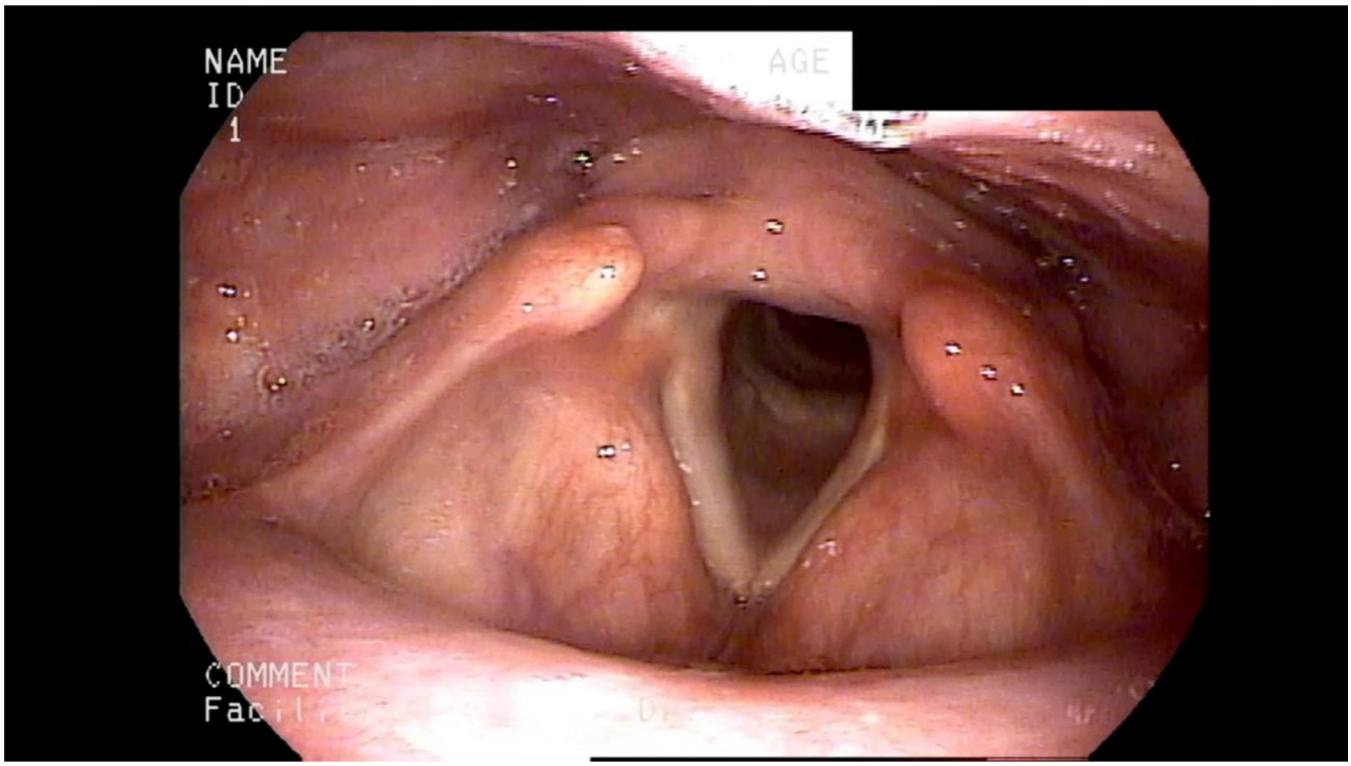

Figure 4.
Endoscopic view of oropharynx, pharynx, and larynx. A laryngoscope is passed transnasally to directly visualize the oropharynx, pharynx, and larynx during swallowing.

Figure 5.
Example of an expiratory muscle strength training device. Image of the EMST 150® pressure-threshold device; (Aspire, LLC; Atlanta, GA) used as a rehabilitative strategy to strengthen expiratory muscles. The device consists of a calibrated, one-way, spring-loaded valve and pressure resistance can be set from 30–150 cmH2O.

Table 1.

Common impairments observed in different phases of swallowing in PD dysphagia (25,28,81,187,197)

Phase of swallowing	Observed impairments
Oral preparatory/transit	Impaired mandible movement
	Jaw rigidity
	Xerostomia
	Sialorrhea
	Impaired lingual movement/pressure generation
	Tongue pumping/rocking
	Premature spillage/reduced posterior bolus containment
	Reduced spontaneous swallowing
	Piecemealed deglutition
	Oral residue
Pharyngeal	Delayed swallow reflex
	Decreased hyolaryngeal elevation
	Impaired laryngeal/pharyngeal movement due to anterocollis
	Impaired pharyngeal contraction
	Aspiration
	Diminished/absent cough response to aspiration
	Decreased cricopharyngeal opening
	Residue in the valleculae and pyriform sinuses
Esophageal	Dysfunction of the upper esophageal sphincter
	Impaired esophageal peristalsis/non-propulsive contractions
	Esophageal spasms Repetitive contractions

Table 2.

Penetration-aspiration scale (PAS): An 8-point ordinal scale used to indicate the depth to which material enters the airway and whether penetrated or aspirated material is ejected from the airway. (Reprinted with permission from from SpringerNature: SpringerNature, Dysphagia, A penetration-aspiration scale, Rosenbek et al. [1996]). [103]

Score	Airway Safety	Description
1	No penetration	Contrast material does not enter airway
2	Penetration	Contrast material enters airway, remains above vocal folds, ejected from airway
3	Penetration	Contrast material enters airway, remains above vocal folds, not ejected from airway
4	Penetration	Contrast material contacts vocal folds, ejected from airway, no visible residue
5	Penetration	Contrast material contacts vocal folds, not ejected from airway, visible residue
6	Aspiration	Contrast material passes below vocal folds, ejected from airway or into larynx
7	Aspiration	Contrast material passes below vocal folds, not ejected from airway despite patient effort
8	Aspiration	Contrast material passes below vocal folds, absence of patient effort to eject