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ORIGINAL RESEARCH

Measurement of Voluntary Cough Production and Airway Protection in Parkinson Disease

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Abstract

Objective: To examine relations between peak expiratory (cough) airflow rate and swallowing symptom severity in participants with Parkinson disease (PD).

Design: Cross-sectional study.

Setting: Outpatient radiology clinic at an acute care hospital.

Participants: Men and women with PD (N=68).

Interventions: Participants were cued to cough into an analog peak flow meter then swallowed three 20-mL thin liquid barium boluses. Analyses were directed at detecting potential relations among disease severity, swallowing symptom severity, and peak expiratory (cough) airflow rate.

Main Outcome Measures: Peak expiratory (cough) airflow rate and swallow symptom severity.

Results: Peak expiratory (cough) airflow rate varied significantly across swallowing severity classifications. Participants with more severe disease displayed a significant, linear decrease in peak expiratory (cough) airflow rate than those participants with earlier stage, less severe disease. Swallowing symptom severity varied significantly across groups when comparing participants with less severe PD with those with more severe PD. Participants with early stage PD demonstrated little to no swallowing symptoms and had the highest measures of peak expiratory (cough) airflow rate. In contrast, participants with the most severe swallowing symptoms also displayed the lowest measures of peak expiratory (cough) airflow rate.

Conclusions: Relations existed among PD severity, swallowing symptom severity, and peak expiratory (cough) airflow rate in participants with PD. Peak expiratory (cough) airflow rate may eventually stand as a noninvasive predictor of aspiration risk in those with PD, particularly those with later stage disease. Inclusion of peak expiratory (cough) airflow rates into existing clinical swallowing assessments may increase the sensitivity and predictive validity of these assessments.

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Parkinson disease (PD)[1] is neurodegenerative disorder primarily affecting adults. Cardinal symptoms associated with PD include rigidity, bradykinesia, resting tremor, and postural instability.[2] There is no cure for PD; although medications alter its progression,[3] significant morbidities remain, particularly as the disease evolves. This evolution initially targets and destroys subcortical grey matter regions prior to progressing to cortical regions, presenting first within the temporal mesocortex.[4-6] Later on, larger regions of the neocortex yield to the disease, including high-order sensory association and prefrontal areas. Ultimately, the degenerative disease effects reach first-order sensory association areas and premotor fields, in some patients terminating within the primary sensorimotor cortex.[4-6] Later on, progressive degeneration of ascending and descending neural pathways impairs a range of physiological functions, including life-sustaining mechanisms of airway protection, including breathing, coughing, and swallowing, that arise from a set of shared subcortical substrates.[7-9]

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With regard to breathing, several investigations have shown involvement of upper airway musculature and resultant airflow limitation[10-15] (secondary to increased resistance), progressive declines in respiratory muscle strength,[16] and diaphragmatic instability and tremor.[17] Cough impairment in PD is typically attributed to disease-related rigidity within chest wall structures,[18-21] which coupled with reduced respiratory muscle strength precludes the generation of sufficiently high-velocity, high-volume airflow for airway clearance. Early in the disease, motoric components of cough are primarily affected with later decline in cough sensory capabilities, reducing cough sensory thresholds in response to stimulation.[22-24] Functional associations between cough and swallowing function further complicate the clinical presentation.[25-27]

Swallowing dysfunction or dysphagia is a key clinical feature, particularly among patients in the mid to later stages of PD[28-30] and varies relative to numerous factors (eg, age, sex, disease duration, presence or absence of dementia).[31] The incidence of dysphagia in individuals is estimated at 18.5% to 100%, with aspiration pneumonia being the leading cause of death.[13,32,33] Dysphagia in PD results from disrupted motor function secondary to rigidity, hypokinesia, and tremor similar to those mechanisms that impair cough.[34,35] The motor dysfunction affects every stage of swallowing, potentially causing lingual tremor, difficulty with bolus manipulation, delayed onset of the pharyngeal swallowing response, reduced rate of spontaneous swallowing, increases in postswallow oral and pharyngeal residue, decreased range of motion of the epiglottis, slowing of laryngeal elevation and excursion during pharyngeal swallowing, laryngeal penetration, aspiration, incoordination of upper esophageal sphincter opening, and disruption in swallowing-respiratory coordination.[34-38]

Clear relations exist between cough and aspiration risk in individuals with PD[22-24,39,40] and can be characterized through analysis of cough waveform measures and swallowing physiology.[39,41,42] Previous studies used high-tech methods for cough collection and measurement, consisting of a pneumotachograph and associated equipment, followed by digitization and computerized analysis of cough waveforms. In contrast with these methods, a low-tech method involving simple, 1-step collection of voluntary peak expiratory flow rate (PEFR), using a hand held analog PEFR meter, has emerged as a sensitive and noninvasive means of estimating cough strength. Phase 1 of this 2-part study (previously published)[43] established the validity and sensitivity of an analog PEFR meter for discriminating individuals with PD from healthy controls and detecting differences in PEFR relative to sex. However, if this process is to transition to routine clinical use, additional information is needed regarding the relations among breathing, coughing, and swallowing to enhance the sensitivity and predictive validity of existing assessments of airway protection in those with PD. This phase 2 article examines potential relations between PEFR and swallowing severity as measured by the penetration aspiration scale (PAS) score.[44] Additional objectives were to examine differences in voluntary PEFRs (at various perceived cough strengths) as a function of age, sex, and disease severity and compare PEFRs from our cohort of participants with PD with those previously (during phase 1) obtained from a cohort of healthy controls. We hypothesized that participants with moderate to severe PD would demonstrate significant impairment in both PEFR and measures of swallowing severity compared with participants with mild, early stage PD.

List of abbreviations:

H&Y	**Hoehn and Yahr**
PAS	**penetration aspiration scale**
PD	**Parkinson disease**
PEFR	**peak expiratory flow rate**
VFSS	**videofluoroscopic swallowing study**

Methods

Sample size and power calculations were performed using PASS[a] and SAS (macro)[b] based on a 1-way analysis of variance for the primary dependent variable, peak cough airflow, with level of significance set at .05. Our preliminary data of participants evaluated for cough response (strong) using a pneumotachograph and reported mean peak cough airflow for healthy adults as 7.58±2.5L/s and mean peak cough airflow for participants with PD participants as ranging from 6.93±1.8 to 5.98±2.4L/s (severe). These data assumed cough response would show a linear trend in both healthy and participants with PD and that the difference between the healthy and groups with PD can reach ≥1.6L/s (difference between the healthy and PD participants on pneumotachograph readings). Given an estimated event rate of .32 for laryngeal penetration or aspiration in participants with PD obtained from unpublished preliminary data, it was estimated that the number of individuals in this study (where the probability of aspiration occurring > the probability of aspiration not occurring or odds ratio>1; odds ratio of 1.7, $1-\beta=80\%$, $\alpha=.05$) would be 128. Given an anticipated attrition rate of slightly >2%, our targeted enrollment was 132 participants with PD.

Participants were recruited from regional support groups for inclusion in this study. All study-related activities were completed within the radiology departments of affiliated hospitals (University of Florida Health Center for Movement Disorders and Neurorestoration in Gainesville, FL and Memorial Hospital in Jacksonville, FL). Those interested in participating were considered for inclusion based on the following criteria: diagnosis of PD by a neurologist (all severity levels accepted); 30 to 80 years of age; nonsmoking or no smoking within the previous 5 years; no history of head and neck cancer, asthma, chronic obstructive pulmonary disease, or untreated hypertension; sufficient facial muscle strength to achieve and maintain adequate lip closure around a circular mouthpiece; and cognition within normative limits as determined by informal interactions between the researchers and participants. If a participant's cognitive status was called into question at any point, the Mini-Mental State Examination[45] was administered, and a score ≥27 was required to continue on in the study. No participants demonstrated overt signs of cognitive impairment, and additional cognitive assessment was not indicated for any participant. Finally, all participants were to have no neurologic (other than PD) condition that adversely affects respiratory muscles or gas exchange system. All participants taking medication for PD were tested while on the on-medication response curve (determined through manual recording of the time of last medication administration).

After informed consent (University of Florida IRB-01 protocol no. 367-2010; Jacksonville University Institutional Review Board protocol no. 2013-32), all participants underwent measurement of PEFR during voluntary cough. Each participant completed 9 coughs (3 voluntary coughs at 3 perceived strengths of weak, moderate, and strong) into an analog PEFR meter (Mini Wright Peak Flow Meter[c]) (fig 1). Further details regarding the elicitation