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Attentional resource allocation and swallowing safety in Parkinson's disease: A dual task study

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ABSTRACT

Background: Aspiration pneumonia is a leading cause of death in persons with Parkinson's disease (PD). Despite this, the mechanisms underlying dysphagia in this population are unclear. To date, researchers have not investigated the effects of varying cognitive demand on objective measures of swallowing safety. This study assessed whether swallowing safety could be disrupted by increasing cognitive demands during the task of swallowing.

Methods: Twenty participants with moderate PD and dysphagia were tested while completing a novel dual task experimental paradigm under videofluoroscopy. In the dual task condition, participants swallowed 10 cc of thin liquid barium while completing a digits forward task.

Results: Four females and 16 males completed the study. Results revealed differential effects to swallowing safety based on baseline measures of cognitive flexibility and attention. Participants with mild impairment in cognitive flexibility and attention demonstrated cognitive-motor interference with worsening of both swallowing and cognitive performance. In contrast, participants who were most impaired in the domains of cognitive flexibility and attention improved swallowing safety in the dual task condition. Additionally, decreased swallow timing durations existed in the dual task condition compared to the single task condition.

Conclusions: The results of this study support the hypothesis that supramedullary drive can influence the swallowing plan. Additionally, this study highlights the need for cognitive taxing during swallowing evaluations.

1. Introduction

Dysphagia, or disordered swallowing, leads to significant deterioration of health and quality of life, particularly in persons with neurodegenerative diseases, such as Parkinson's disease (PD) [1–3]. Despite this, there is an incomplete understanding of the mechanisms influencing dysphagia. PD leads to changes in all stages of swallowing with oral and pharyngeal deficits and resultant airway compromise [4–8]. These deficits appear to be exacerbated in persons with PD and dementia, often making them less responsive to management with swallowing compensations [9,10]. However, few studies have empirically explored the effects of cognition on swallowing function [11,12], although some have identified dysphagia in populations with cognitive dysfunction [13,14] and there is known activation of fronto-cortical structures during swallowing [15]. No empirical studies exist investigating how varying cognitive demand influences swallowing safety.

In one study a dual task paradigm was used to test the influence of cognition on oropharyngeal swallowing in PD [12]. The dual task condition consisted of participants listening for a target non-word presented aurally while they swallowed 5 ml of water from a cup. The results revealed significantly longer reaction times for the anticipatory stage of swallowing in the dual task condition. This was not observed for the oropharyngeal stage of swallowing. This study did not utilize videofluoroscopy (VFSS) or any other more

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direct swallow visualization technique. Therefore, little is known regarding swallowing safety when assessed under dual task conditions. This swallowing information is especially salient given the high incidence of silent aspiration in PD [16].

A comprehensive understanding of the mechanisms influencing swallowing function is important in order to address the deleterious effects of dysphagia on health and quality of life. Additionally, we can assume the likelihood that swallowing safety is influenced by modifications to attentional resource allocation is high. Therefore, studies designed to manipulate cognitive demand while measuring swallowing physiology serve to enrich our knowledge of swallowing mechanisms. This study tested the hypothesis that performing concurrent cognitive and swallowing tasks (via a dual task paradigm) would result in decrements to swallowing safety and timing in PD as visualized under videofluoroscopy.

2. Methods

2.1. Participants

This study was a prospective cohort study including 20 participants with idiopathic PD who were consecutively recruited from patients referred for swallowing evaluations at the University of Florida (UF) and Malcom Randall Veterans Administration Medical Center (VAMC) Movement Disorders Centers. Fellowship trained Movement Disorders Neurologists diagnosed PD using the United Kingdom (UK) brain bank criteria [17]. All participants had complaints of dysphagia with evidence of penetration of thin liquid barium on VFSS as assessed by a licensed and certified speech-language pathologist. Table 1 presents demographic information.

2.1.1. Inclusion/Exclusion criteria

Criteria for inclusion were: 1) diagnosis of idiopathic PD (either tremor-predominant or rigid-predominant) by a certified movement disorders neurologist; 2) Hoehn & Yahr stages II-III; 3) stabilization on one or more anti-PD meds; 4) adult between the ages of 60 and 85 years; 5) dysphagic as per criteria listed above; 6) non-demented as measured by the Dementia Rating Scale-II [18]; 7) willingness and capability of providing informed consent; 8) and normal hearing thresholds for the participant's age or when appropriately aided. Exclusionary criteria were history of any of the following: 1) Deep Brain Stimulation (DBS), pallidotomy, or thalamotomy; 2) other neurological disorder; 3) developmental speech or language disorder; 4) any other motor speech or language disorder; 5) Alzheimer's disease or semantic dementia; 6) severe depression, anxiety, or apathy; and 7) attention deficit disorder.

Table 1
Demographic information, including sex, age, UPDRS, Hoehn & Yahr (H & Y) score, years since diagnosis (PD Dx), and education for each participant. These data were compiled from medical record review and responses from participant inquiry.

Participant code	Sex	Age	UPDRS	H & Y	PD Dx	Education
1	M	66	32	2	11	14
2	M	74	23	2	6	20
3	M	65	58	3	9	20
4	M	80	37	3	9	20
5	M	65	22	2	4	20
6	M	66	43	2	10	20
7	F	76	33	2	8	12
8	F	77	29	2	4	12
9	M	60	27	2.5	8	16
10	M	80	44	2	5	16
11	M	71	25	2	1	11
12	F	75	24	2	4	16
13	M	74	25	2	1	20
14	M	75	48	3	10	20
15	M	70	28	2	5	16
16	M	73	33	3	11	20
17	M	67	24	2	2	20
18	F	72	35	3	11	16
19	M	75	29	2	8	16
20	M	67	42	2.5	10	12
	16 (M) 4 (F)	71.4 (9.67)	33.05 (9.67)	13 (H&Y 2) 2 (H&Y 2.5) 5 (HY& 3)	6.85 (3.39)	16.85 (3.30)

2.2. Study design

All participants underwent two different phases of study which lasted a total of approximately an hour and a half. Participants with PD were tested within the window of optimized medication function (i.e., 1 h after taking anti-PD medications). Prior to completion of any tests, the participant provided informed consent (UF IRB# 518–2008).

2.2.1. Phase 1: cognitive testing procedures

The first half of the experimental visit included assessment of study eligibility and neuropsychological status. The neuropsychological testing included: 1) DRS-II, a valid mental screening test of cognitive functioning in patients with PD [18]; 2) digit span forward, backward, and ordering to assess working memory [19,20]; and 3) Trails A & B and Stroop color-word and color-word interference tasks for assessment of cognitive flexibility and attention [21].

2.2.1.1. Training on experimental procedures. Prior to the experimental VFSS, participants were trained on the experimental task. Participants were given small cups filled with water (instead of barium) to swallow. Participants were trained to 90% success prior to enrollment in the experimental paradigm (described in detail below).

2.2.2. Phase 2: experimental procedures

2.2.2.1. Videofluoroscopic (VFSS) procedures. The experimental dual task procedures took place in the Department of Radiology at the Malcom Randall VAMC, Gainesville, FL, using videofluoroscopy. Participants were seated upright and images of barium swallows were recorded in the lateral view. A properly collimated Phillips Radiographic/Fluoroscopic unit that provides a 63-kV, 1.2-m-A type output for full field of view mode was utilized. Fluoroscopic images were recorded to a Kay Elemetrics Swallowing Signals Lab (Kay Elemetrics, Lincoln Park, NJ) using a digital scan converter and electronically recorded at 30 frames per second. The field of view allowed for a complete visualization of the oral and pharyngeal structures involved in swallow.

2.2.2.2. Cognitive task. The cognitive task used in the experimental paradigm was a modified digit span forward with six digits. The participants were instructed to listen to the aurally presented span of digits and then recite the digits. Accuracy of responses was assessed by determining proportion of correctly recalled digits. Previous studies revealed that participants began to demonstrate greatest breakdown in digit span forward following presentation of five digits [22,23]. Therefore, six digits were chosen to challenge participants, while still allowing sufficient success to determine dual task effects. Responses were transcribed online and accuracy was assessed following the experimental paradigm.

2.2.2.3. Motor task. The motor task for the dual task paradigm was the swallowing of 10 cc of thin barium contrast by small cup (Liquid E-Z Paque Barium Sulfate Suspension; 60% w/v, 41% w/w; from E-Z-EM). The cup for self-feeding was selected to approximate everyday feeding conditions. In the single swallow task, participants were instructed to "empty the barium into [your] mouth and swallow when [you're] ready."

2.2.2.4. Dual task. The experimental paradigm consisted of single (cognitive and swallow) and dual task (cognitive plus swallow) conditions. Participants completed the cognitive task independently of the swallow task (single task cognitive condition) or the swallow task independently of the cognitive task (single task swallow condition). Under dual task conditions, the participants were given the cup of barium to hold and instructed, "I will now read you six numbers, please give me the numbers forward after you swallow." Then, the numbers were read aloud by the examiner, at a rate of approximately one per second. Following this, participants immediately brought the cup to their mouth, swallowed the liquid, and then recited the numbers. Each single task (digits forward and swallow) was completed five times, and the dual task (digits forward while swallowing) was completed five times. The total number of swallows was limited as not to create overexposure to radiation and excessive ingestion of barium for participants. The same cognitive stimuli were used for all participants, but all trials (both single and dual task) were randomized.

2.3. Data analysis and outcome measures

All swallowing measurements were completed by an examiner trained in the analysis of videofluoroscopic swallow studies blinded to participant identity and condition. Analysis was completed frame by frame to ensure accuracy and reliability of measurement.

2.3.1. Primary outcome: swallowing safety

Swallowing safety for each swallow was quantified using the Penetration–Aspiration (PA) scale [24]. The PA scale is a validated, ordinal scale used to measure whether or not material entered the airway and if it did, whether the residue remained or was expelled.