

## PAPER

## Swallowing and voice effects of Lee Silverman Voice Treatment (LSVT®): a pilot study

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**Objective:** To define the effects of Lee Silverman Voice Treatment (LSVT®) on swallowing and voice in eight patients with idiopathic Parkinson's disease.

**Methods:** Each patient received a modified barium swallow (MBS) in addition to voice recording before and after 1 month of LSVT®. Swallowing motility disorders were defined and temporal measures of the swallow were completed from the MBS. Voice evaluation included measures of vocal intensity, fundamental frequency, and the patient's perception of speech change.

**Results:** before LSVT®, the most prevalent swallowing motility disorders were oral phase problems including reduced tongue control and strength. Reduced tongue base retraction resulting in residue in the vallecula was the most common disorder in the pharyngeal stage of the swallow. Oral transit time (OTT) and pharyngeal transit time (PTT) were prolonged. After LSVT®, there was an overall 51% reduction in the number of swallowing motility disorders. Some temporal measures of swallowing were also significantly reduced as was the approximate amount of oral residue after 3 ml and 5 ml liquid swallows. Voice changes after LSVT® included a significant increase in vocal intensity during sustained vowel phonation as well as during reading.

**Conclusions:** LSVT® seemingly improved neuromuscular control of the entire upper aerodigestive tract, improving oral tongue and tongue base function during the oral and pharyngeal phases of swallowing as well as improving vocal intensity.

Reduced vocal intensity is a known complication of Parkinson's disease.<sup>1–3</sup> It may reduce the patient's ability to produce intelligible speech and as a result, limit their ability to function fully in society.<sup>4</sup> Vocal intensity depends on the integrity of vocal fold adduction<sup>5</sup>, shape of the vocal tract,<sup>6</sup> and subglottic air pressure.<sup>7</sup> All of these factors may be affected in the course of Parkinson's disease.<sup>1–2, 8</sup> The incidence of voice disorders, including breathiness, hoarseness, roughness, and tremulousness, is reported to be as high as 89% in patients with Parkinson's disease.<sup>1</sup> Logemann *et al*<sup>1</sup> indicated that these patients usually show other vocal tract problems in addition to voice disorders including articulatory disturbance, speech rate disorders, and hypernasality.

In addition to voice and articulatory disorders, swallowing disorders have been reported in as many as 95% of patients with Parkinson's disease.<sup>9–13</sup> Dysphagia has sometimes been described as the presenting feature of Parkinson's disease.<sup>14</sup> It may cause life threatening pneumonia,<sup>15</sup> although it is rarely severe enough to require non-oral feeding.<sup>16</sup>

Swallowing disorders in patients with Parkinson's disease have been described for all phases of the swallow.<sup>17</sup> Swallow motility disorders reported to affect the oral phase of the swallow include disturbed lingual motility resulting in prolonged oral transit time,<sup>18</sup> difficulty in bolus formation, and hesitancy in initiation of the oral phase of the swallow.<sup>13</sup> Pharyngeal phase disorders reported include delayed pharyngeal response and decreased pharyngeal contraction.<sup>10–11, 19</sup>

Most investigations of oropharyngeal dysfunction in patients with Parkinson's disease have evaluated the effect of the disease on either speech or swallowing.<sup>11–12</sup> Only one group has examined the effects of Parkinson's disease on both speech and swallowing.<sup>9</sup> Blonsky *et al*<sup>9</sup> used simultaneous videofluoroscopic and voice recordings which showed reduced elevation of the posterior and middle portions of the tongue during speech and swallowing; they concluded that the motor abnormality of the tongue might reflect rigidity rather than weakness.

Short and long term efficacy data have been published supporting the effectiveness of intensive voice treatment for patients with Parkinson's disease in improving speech production,<sup>20–21</sup> particularly for the Lee Silverman Voice Treatment program (LSVT®).

This program was designed to improve the perceptual characteristics of voice by targeting the underlying motor disorder associated with the disease. This is accomplished through training high phonatory effort tasks that stimulate increased vocal fold adduction and respiratory support. It is aimed at increasing amplitude of voice (laryngeal) output<sup>22</sup> to alleviate the effect of hypokinesia<sup>23</sup> on the respiratory and phonatory systems of patients with Parkinson's disease. Effects of LSVT® on vocal intensity have been reported by several investigators<sup>8, 24–26</sup> who indicated a statistically significant increase in vocal intensity in a group of patients with Parkinson's disease immediately after a course of LSVT® compared with an age matched group of patients who received placebo speech therapy focusing only on respiration.<sup>26</sup>

Clinicians who are experienced in using LSVT® have reported that patients with idiopathic Parkinson's disease undergoing LSVT® comment that their swallowing improved during and after therapy. No study has yet been completed to validate these observations. This pilot study was undertaken to evaluate swallowing and voice changes in eight patients with idiopathic Parkinson's disease after receiving LSVT®.

**Abbreviations:** PD, Parkinson's disease; MBS, modified barium swallow; OTT, oral transit time; PTT, pharyngeal transit time; LSVT®, Lee Silverman Voice Treatment Program; CP, cricopharyngeal; OPSE, oropharyngeal swallow efficiency; ORES, percentage of oral residue; PRES, percentage of pharyngeal residue; ASPB, aspiration before the swallow; ASPD, aspiration during the swallow; PRT, pharyngeal transit time; SPL, sound pressure level;  $f_0$ , fundamental frequency.

**Table 1** Subjects' demographic and staging characteristics

Subject	Sex	Age	Stage*
1	M	61	III
2	F	48	II
3	M	57	IV
4	M	72	NA
5	M	77	III
6	F	57	II
7	M	75	IV
8	M	77	II

\*Hoehn and Yahr rating scale; NA=Not available.

## METHODS

### Patients

Eight patients, six men (age range 57–77, mean age 69.8) and two women (ages 48 and 57) with idiopathic Parkinson's disease referred for LSVT<sup>®</sup> by their neurologist, participated in this study (table 1). No patient had a history of gastrointestinal disease, gastro-oesophageal surgery, head and neck cancer, or any other neurological disorders that may affect swallowing. Patients were recruited regardless of sex or minority status. Those with idiopathic Parkinson's disease were chosen to form a homogeneous group and to exclude the possibility of additional neurological deficits that may be present with other Parkinson's disease categories. The level of clinical disability was rated using the Hoehn and Yahr scale.<sup>27</sup> This rating scale ranges from stage I being the mildest level of disability such as unilateral involvement, to stage V, the most severe level of disability such as confinement to a wheelchair. Three patients were diagnosed as stage II, two were in stage III, two were in stage IV and one was not staged at the time of the study. No patient's medication regimen was changed during the 4 weeks of their participation in the study.

### Procedures

Each patient was evaluated before starting LSVT<sup>®</sup> and immediately after. The evaluations consisted of assessment of voice function repeated three times before and twice after LSVT<sup>®</sup>. Assessment of swallowing was carried out once before and once after treatment. No patient included in this study received any other swallow or speech therapy before or during the study. Studies before and after LSVT were done at the same time of day and medicine cycle for each patient.

### Assessment of swallowing

A videofluoroscopic study of the oropharyngeal swallow was completed using a standard protocol.<sup>28</sup> This protocol consisted of 14 swallows, two each of 1 ml, 3 ml, 5 ml, 10 ml and cup drinking of barium liquid, 2 ml of swallows of barium pudding (paste) and two pieces (1/4 each) of a Lorna Doone cookie coated with barium to chew and swallow. During the radiographic study, patients were seated and viewed in the lateral plane. The fluoroscopic tube was focused on the lips anteriorly, the cervical vertebra posteriorly, the soft palate superiorly, and the cervical oesophagus inferiorly. The videofluoroscopic studies were recorded on a VHS video recorder for later slow motion and frame by frame analysis.

### Assessment of voice

Voice assessment consisted of perceptual and acoustic evaluation as defined by Ramig.<sup>29</sup> The perceptual analysis included the speech assessment scale (National Technical Institute for the Deaf),<sup>29</sup> the visual analogue scale (adapted from Schiffman *et al*<sup>30</sup>), and the voice handicap index<sup>31</sup> which is a 30 item self assessment scale that requires the patients to describe their voices and assess the effect(s) of their voices on their lives. The

speech assessment scale is a six point self assessment speech intelligibility scale concerning the ability to understand the patient's speech. The visual analogue scale is a self assessment scale for speech and voice quality including questions on vocal roughness, tonicity, and loudness. Tasks completed during each voice recording session were sustained vowel phonation, reading the "rainbow passage"<sup>32</sup> and talking about their happiest day (an emotionally charged monologue in which the subject talks about his or her happiest day).

### LSVT<sup>®</sup> Treatment

After baseline assessment of swallowing and voice, each patient received 16 sessions of LSVT<sup>®</sup>. The treatment was conducted over a 4 week period with therapy being given four times a week for 50–60 minutes at each session.<sup>22</sup> During each therapy session, patients practised three daily exercises including maximum duration of sustained vowel phonation, maximum fundamental frequency range, and maximum functional speech loudness drill. Patients were also trained to use a louder voice while speaking, to accurately judge their loudness, and "to feel effort, feel loudness—that, is what it needs to feel like when you talk so people understand you." In addition, all patients did daily homework and carry over exercises focusing on "think loud."

### Data reduction

#### Swallowing measures

Videofluorographic data reduction involved two types of analysis: (1) identification of physiological motility disorders in the oropharyngeal swallow, and (2) temporal measures of the oropharyngeal swallow. Motility disorders were identified by reviewing the videotape of each swallow in slow motion. Temporal measures and observations were completed for each swallow as described in Pauloski *et al*<sup>33</sup> and Lazarus *et al*<sup>34</sup>: (1) oral transit time; (2) pharyngeal transit time; (3) pharyngeal delay time; (4) pharyngeal response time; duration (in seconds) of (5) tongue base movement to the posterior pharyngeal wall; (6) tongue base contact to the pharyngeal wall at mid-C2 level; (7) tongue base contact to the posterior pharyngeal wall at inferior C2 level; (8) tongue base contact to the posterior pharyngeal wall at superior C3 level; and (14) the time interval (in seconds) between first laryngeal entrance closure and first cricopharyngeal opening; (9) velopharyngeal closure; (10) laryngeal closure; (11) cricopharyngeal (CP) opening; (12) hyoid movement; (13) laryngeal elevation. In addition, observations were made regarding presence or absence of aspiration and approximate per cent of the bolus remaining in the oral cavity (oral cavity residue) and in the pharynx (pharyngeal residue) after each swallow.

In both analyses, the clinician who performed the data reduction was not informed as to whether the radiographic studies of a patient were done before or after the LSVT<sup>®</sup>. No clinician who provided LSVT<sup>®</sup> was involved in the swallow analysis.

The oropharyngeal swallow efficiency (OPSE) measure was calculated for each swallow as follows:

$$OPSE = \frac{100 - (ORES + PRES + ASPB + ASPD)}{OTT + PTT}$$

where ORES=percentage of oral residue; PRES=percentage of pharyngeal residue; ASPB=aspiration before the swallow; ASPD=aspiration during the swallow; OTT=oral transit time; PRT=pharyngeal transit time.

This index was developed as a global measure to reflect the ability of the oral cavity and pharynx to move food efficiently and safely into the oesophagus.<sup>35</sup>

### Voice measures

Sound pressure level (SPL) was obtained using signals from the sound level meter recorded during sustained phonation

and reading. These signals were digitised at 1kHz and analyzed by custom software to derive the mean (SEM) for intensity. Mean fundamental frequency ( $f_0$ ) during reading was obtained after digitising the voice recordings at 5 kHz and analyzing them with CSpeech on computer.

### Statistical analysis

Changes in swallowing measures before and after LSVT® were assessed for statistical significance separately for each bolus type (consistency/volume combination). No statistical test across bolus types was done. Data were analyzed using a two factor analysis of variance (ANOVA) with time and person as the two factors. Statistical significance was indicated if  $p < 0.05$ . Analysis of data was conducted using PROC MIXED in SAS. A similar ANOVA was done to compare measures of vocal intensity and fundamental frequency before and after treatment. Correlations between voice and swallowing changes as an effect of LSVT® were tested using Pearson correlation coefficients.

## RESULTS

Comparison of the various swallow disorders and measures and the voice measures disclosed some differences after LSVT®.

### Swallow motility disorders

Table 2 summarises the frequency of occurrence of swallowing motility disorders before and after LSVT®. Before LSVT®, reduced tongue coordination and reduced tongue lateralisation impaired the ability of the tongue to hold the bolus as a cohesive mass before the swallow and were the only swallow motility disorders found in the oral preparatory phase of the swallow. After LSVT®, these disorders were identified in fewer patients during all seven types of swallows. Reduced tongue lateralisation on the cookie bolus before LSVT® treatment disappeared after treatment.

Swallow motility disorders during the oral phase of swallowing included reduced anterior to posterior tongue movement, anterolateral tongue stabilisation, and the characteristic “rocking-like” tongue motion resulting in prolongation of oral transit time.<sup>11</sup> This characteristic movement disappeared after LSVT® therapy resulting in reduction in oral transit time. Reduced tongue strength resulting in tongue and/or palatal residue after the swallow was reduced by 50% during swallows of liquid, by 12.5% during swallows of paste, and by 25% during swallows of cookie after treatment.

Reduced anterior/lateral stabilisation of the tongue increased as bolus volume increased, resulting in subsequent splashing of the bolus throughout the oral cavity as well as increased oral residue after the swallow and disappeared after LSVT®.

Reduced anterior to posterior tongue movement was a common disorder before LSVT®. After LSVT®, improvement of this disorder was dependent on the size and viscosity of the bolus. This disorder disappeared in all patients during cup drinking.

Delayed triggering of the pharyngeal swallow, usually resulting in prolongation of the PTT and mild laryngeal penetration before the swallow, occurred often before LSVT®. After LSVT®, this disorder completely disappeared during swallows of liquids with a 25% and 66% reduction in the frequency of this disorder in paste and cookie, respectively, resulting in reduction in PTT and percentage of laryngeal penetration before the swallow.

Reduced tongue base retraction and delayed laryngeal vestibule closure were the most common swallow motility disorders during the pharyngeal phase of the swallow. Reduced tongue base retraction, resulting in residue over the base of the tongue, in the valleculae, or the posterior pharyngeal wall increased in severity as bolus size and consistency increased. After LSVT®, there was a 50% reduction in the frequency of this disorder, resulting in reduction in the amount of residue over the tongue base and in the valleculae.

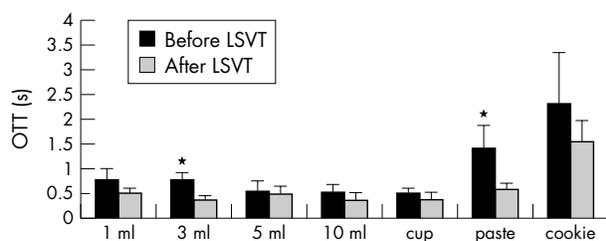
Delayed laryngeal vestibule closure occurred often, resulted in penetration of material into the airway entrance, and did not change after LSVT®. However, this penetration was cleared as the swallow progressed and never resulted in aspiration. No patient had reduced closure of the entire larynx during swallow either before or after LSVT®. No aspiration was found in any patient before, during, or after any swallows before or after LSVT®.

### Effects of LSVT® on temporal measures of swallowing, residue, and oropharyngeal swallow efficiency

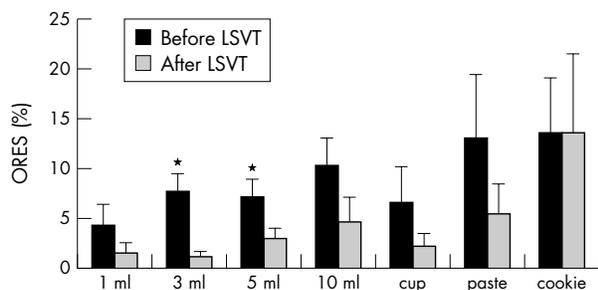
The LSVT® significantly affected OTT, as well as approximate percentage of oral residue and oropharyngeal swallow efficiency. For all swallow volumes and consistencies, OTT was reduced after LSVT®, significantly so for 3 ml liquid bolus swallows ( $p \leq 0.05$ ; fig 1). The percentage of oral residue was reduced after LSVT® for all swallow volumes and consistencies except cookie. This reduction was significant for 3 and 5 ml liquid swallows ( $p \leq 0.05$ ; fig 2). For all swallow volumes and consistencies except cookie, there was an improvement in

**Table 2** Swallowing motility disorders before and after LSVT®; numbers refer to number of subjects who demonstrated the disorder on swallows of each bolus volume

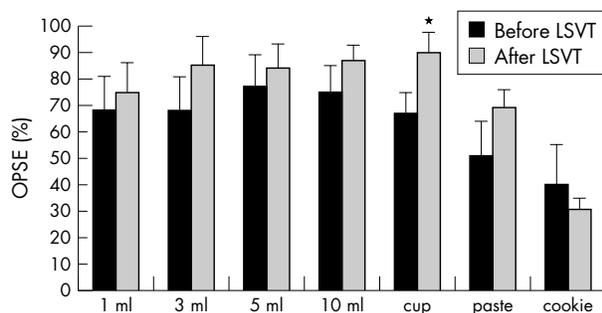
Motility disorder	Bolus volume													
	1 ml		3 ml		5 ml		10 ml		Cup drinking		Paste		Cookie	
	Pre Tx	Post Tx	Pre Tx	Post Tx	Pre Tx	Post Tx	Pre Tx	Post Tx	Pre Tx	Post Tx	Pre Tx	Post Tx	Pre Tx	Post Tx
Reduced tongue coordination	4	0	4	1	1	0	1	2	2	1	5	2	5	4
Reduced vertical tongue movement	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Reduced AP tongue movement	5	2	5	1	3	2	3	2	5	0	6	6	8	8
Reduced tongue stabilization	1	0	1	0	2	0	2	0	2	0	0	0	0	0
Reduced tongue lateralization	0	0	0	0	0	0	0	0	0	0	1	0	5	0
Reduced tongue strength	8	3	8	5	8	4	8	6	8	4	8	7	8	6
Rocking-like movement	0	0	1	0	1	0	1	1	1	0	1	0	2	0
Delayed pharyngeal swallow	2	0	2	0	0	0	0	0	0	0	4	1	6	4
Reduced tongue base retraction	6	3	7	3	6	4	8	4	8	4	8	4	7	6
Slowed/delayed vestibule closure	0	3	0	1	1	2	2	2	2	2	1	1	1	1
Bilateral pharyngeal weakness	0	0	1	0	2	0	4	2	3	2	3	2	3	2
Dipper swallow	1	0	1	1	1	0	1	1	0	0	1	0	1	1
Difficulty clearing pharyngeal residue	0	0	0	0	0	0	0	0	0	0	2	1	1	1
Functional swallow	4	7	4	7	6	5	5	7	5	6	2	8	1	2



**Figure 1** Mean (SEM) oral transit time (OTT) before and after LSVT<sup>®</sup> (\* $p \leq 0.05$  before LSVT<sup>®</sup> v after LSVT<sup>®</sup>).



**Figure 2** Mean (SEM) approximate oral residue percentage (ORES) before and after LSVT<sup>®</sup> (\* $p \leq 0.05$  before LSVT<sup>®</sup> v after LSVT<sup>®</sup>).



**Figure 3** Mean (SEM) oropharyngeal swallow efficiency (OPSE) before and after LSVT<sup>®</sup> (\* $p \leq 0.05$  before LSVT<sup>®</sup> v after LSVT<sup>®</sup>).

OPSE after the swallow, significantly so during cup drinking ( $p \leq 0.05$ ; fig 3).

#### Effects of LSVT<sup>®</sup> on perceptual and acoustic parameters of voice

Perceptual and acoustic data and significance test results are summarised in table 3. Analysis of vocal intensity during sustained vowel phonation disclosed a statistically significant main effect of LSVT<sup>®</sup>. Mean vocal intensity was 74.6 dB at 30 cm before LSVT<sup>®</sup> and 83.0 dB at 30 cm after ( $p < 0.001$ ).

Vocal intensity during reading of the “rainbow passage” significantly increased after LSVT<sup>®</sup>. Average vocal intensity was 71.6 dB before LSVT<sup>®</sup> and 77.9 dB after ( $p < 0.001$ ). A significant change in the mean value for vocal intensity after LSVT<sup>®</sup> was also noted during reading of the “happy day” passage. The average intensity was 70.1 dB before LSVT<sup>®</sup> and 75.3 dB after ( $p = 0.002$ ).

The average fundamental frequency during reading of the “rainbow passage” increased after LSVT<sup>®</sup> but not significantly so. The same findings were noticed during reading of the “happy day” passage.

Before to after LSVT<sup>®</sup> comparison of scores obtained from the speech assessment scale, visual analogue scale and voice handicap index showed improvement in the perception of speech indicating better speech intelligibility. These changes were not statistically significant, however.

#### Correlation of differences in voice and self perception variables with differences in swallowing variables

For all swallow volumes and viscosities, no consistent pattern of correlation was seen between changes in voice and self perception variables and changes in swallowing measures across bolus types. The number of significant correlations obtained from statistical analysis did not exceed the number expected by chance.

#### DISCUSSION

The purpose of this pilot study was to document the effects of LSVT<sup>®</sup> on swallowing and voice in patients with idiopathic Parkinson’s disease. Before LSVT<sup>®</sup>, patients with Parkinson’s disease experienced swallow motility patterns that affected all phases of the swallow. The incidence of the swallow motility disorders was consistently reduced after LSVT<sup>®</sup> and some temporal swallowing measures improved significantly. The motility disorders in patients in this study before LSVT<sup>®</sup> are similar to the disorders reported by other investigators.<sup>12 14 16 18–19</sup> Our findings confirm those of other investigators<sup>12 18</sup> who indicated that patients with Parkinson’s disease usually demonstrate multiple swallowing disorders. However, our study did not show any evidence of cricopharyngeal dysfunction as reported in the literature.<sup>36</sup>

The frequency of reduced range of motion or coordination of the tongue in this study is consistent with previous reports.<sup>10 18</sup> These lingual disorders decreased the patients’ ability to chew the cookie bolus completely, to propel it efficiently from the mouth, and led to accumulation of oral residue over tongue and palate with frequent repeated swallows needed to clear the residue.

One of the common effects of Parkinson’s disease on the oral tongue is the characteristic “rocking like” tongue movement reported here. This back and forth tongue movement ended when sufficient tongue elevation was maintained to propel the bolus posteriorly into the pharynx. This

**Table 3** Voice and self perception variables (mean (SEM) before and after LSVT<sup>®</sup>)

	Before LSVT <sup>®</sup>	After LSVT <sup>®</sup>	Difference	pValue
*SPL /a/ (n=8)	74.6 (2.5)	83.0 (1.8)	8.4 (1.5)	<0.001
*SPL-rainbow passage (n=8)	71.6 (1.5)	77.9 (1.5)	6.3 (1.0)	<0.001
*SPL-happy day (n=8)	70.1 (1.5)	75.3 (1.7)	5.2 (1.1)	0.002
f <sub>0</sub> -rainbow passage (n=8)	149.3 (15.0)	158.5 (16.3)	9.1 (4.7)	0.09
f <sub>0</sub> -happy day (n=8)	147.2 (14.5)	146.3 (15.3)	-0.8 (3.1)	0.80
SAS (n=8)	4.2 (0.2)	4.4 (0.3)	0.3 (0.4)	0.50
VAS (n=7)	55.0 (6.2)	59.9 (5.5)	4.9 (9.1)	0.61
VHI (n=7)	2.2 (0.3)	1.7 (0.2)	-0.5 (0.3)	0.14

\*SPL measured at 30 cm; SAS, speech assessment scale (self/perception), 1=worst, 6=best; VAS, visual analogue scale to question “I speak so others understand”, 0=never (worst), 100=all the time (best); VHI, voice handicap index: “People ask me to repeat myself”, 0=never (best), 4=always (worst); fo, fundamental frequency.

movement resulted in prolongation of oral transit time. The occurrence of this disorder in patients with Parkinson's disease might reflect the increased difficulty in switching from the voluntary initiation of the swallow to the more automatic continuation in the pharyngeal phase of swallow, resembling the well known problem of switching to the automatism of walking in patients with Parkinson's disease.

Because rigidity and bradykinesia might affect the coordination of fine motor acts such as tongue movement, reduced anterior and lateral stabilisation of the tongue might be related to the effect of these disorders on the tongue. The reduced tongue strength found in many patients might reflect weakness rather than rigidity as the tongue generally moved to the same extent as in normal subjects.

One of the interesting findings in our study was the decrease in pharyngeal delay with increasing bolus volume. This finding results from increased stimulation of sensory receptors by the increasing bolus volume.

Another important motility disorder demonstrated by our patients was reduced tongue base retraction, which results in residual food remaining in the valleculae. This disorder, in addition to the pharyngeal delay, may be responsible for the erratic absorption of medicines in patients with Parkinson's disease, reducing the response of these patients to medical treatment.

Unlike other investigators<sup>16-19</sup> who reported frequent aspiration among patients with Parkinson's disease, no aspiration was found in any patient in this study. In addition, only mild laryngeal penetration occurred and only in a few patients. This penetration occurred before and during the swallow and might be related to the effect of bradykinesia on laryngeal movements. Absence of aspiration indicates that the laryngeal involvement in these patients was not severe enough to affect airway closure.

Our findings indicate that Parkinson's disease affected the timing measures of the swallow. The OTT was prolonged in patients with Parkinson's disease before LSVT®. This finding is consistent with findings of other investigators<sup>9</sup> who reported increased OTT for patients with Parkinson's disease compared with age matched controls. Unfortunately, other investigators<sup>10-12, 16-18</sup> have not given a specific value for this duration.

Although no previous studies have been done to evaluate the effects of LSVT® on swallowing, the findings of this preliminary investigation suggest that LSVT® may have important effects on the oral and pharyngeal phases of swallow. During the oral preparatory phases, LSVT® was effective in improving bolus control by the tongue. This was manifested by increased ability of the patient to hold the bolus as a cohesive mass before the swallow. It also resulted in reduction of the mean duration of OTT compared with pretreatment. LSVT® was effective in improvement of both oral and pharyngeal (tongue base) lingual function including improvements in anterior/posterior tongue movement, tongue strength, anterior/lateral lingual stabilisation of the bolus, and ability of the patient to lateralise the bolus during chewing of cookie. Interestingly, these lingual effects are not the focus of LSVT®.

Our findings suggest that LSVT® may activate neuromuscular control of the entire aerodigestive tract, improving function in both the oral tongue and the tongue base during the oral and pharyngeal stages of swallowing. This may reflect an overflow of effort from the habituated increase in phonatory effort. LSVT® may also increase the patients' awareness of the overall function of the vocal tract.

Another perspective on why LSVT® may improve swallow comes from two recent PET studies of voluntary swallowing in healthy volunteers.<sup>37-38</sup> These studies found that, besides the primary sensorimotor cortex (pharynx-larynx representation) and brain stem, the other region most strongly activated during voluntary swallowing was the right anterior insular cortex,<sup>37-38</sup> exactly one of the sites that significantly changes

with LSVT.<sup>38</sup> It is therefore likely that improved right anterior insular function (phylogenetically old communication system) may also contribute to the mechanism of improved voluntary swallowing after LSVT.

The LSVT® was also effective in increasing the intensity and the frequency of voice and speech intelligibility, as reported by other investigators.<sup>20-26</sup> Other types of speech treatment are not as effective in patients with Parkinson's disease.<sup>39-40</sup> The positive changes found in this study could be explained by the differences in the style and focus of treatment. Treatment by LSVT® was focusing on intensity of laryngeal (voice) function whereas previous approaches to speech treatment for Parkinson's disease have focused on articulation, rate, and prosody and were not as intensive (four sessions/week for 4 weeks) in nature.

Our findings indicate that the degree of improvement in speech and voice was not consistently correlated across bolus type with the degree of improvement in swallowing. This finding might be due to the lack of a global measure of speech intelligibility in our study. Further research on LSVT® effects on swallow, speech, and voice are needed, particularly on patients with more severe swallowing disorders.

## CONCLUSIONS

This investigation of the effects of LSVT® on the swallow pattern and voice characteristics of patients with Parkinson's disease indicate that it could be considered an effective line of treatment for upper aerodigestive tract dysfunction for voice and swallowing with no hazards or side effects to the patients. Videofluoroscopy with measured amounts of material (calibrated boluses), the "modified barium swallow," was useful in detecting and analyzing swallowing dysfunction in Parkinson's disease.

Lack of consistent correlation between degree of improvement of voice and in swallowing as an effect of LSVT® emphasises the need for a global measure of speech function that would include parameters representing articulation, prosody, and voice. Further studies of the concurrent effects of LSVT® on swallowing, voice, and speech are warranted as are long term follow up investigations of these effects.

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