

## Speech Rehabilitation in Parkinson's Disease

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### ABSTRACT

The purpose of this review was to evaluate the different speech therapy approaches for persons with Parkinson's Disease (PD). Treatment methods reviewed include speech therapy (LSVT), pharmacological therapy and deep brain stimulation (DBS). Recent research data show that speech therapy has proven to be the most effective therapeutic strategy for improving voice and speech function. Pharmacotherapy or DBS methods not combined with speech therapy do not appear to significantly improve voice and speech function in PD across research studies. Possible explanation for this results is that LSVT is the major tool for speech rehabilitation in patients with PD. Research data comparing the efficacy of LSVT LOUD and LSVT ARTIC have confirmed the advantages of LSVT LOUD for the speech therapy in patients with PD

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**Key words:** Parkinson's disease; speech disturbances; rehabilitation strategies

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### INTRODUCTION

Parkinson's disease (PD) is a chronic progressive neurodegenerative disorder with an increasing incidence worldwide. PD is characterized by the idiopathic loss of dopaminergic neurons, primarily in the anterior part of the substantia nigra<sup>[1]</sup>. The main symptoms of PD result from significantly reduced activity of dopaminergic neurons in the pars compacta region of the substantia nigra<sup>[2]</sup>. There are several pathways in the brain connecting other brain areas with the basal ganglia: motor, oculomotor, associative, limbic and orbitofrontal pathways. All these tracts are affected in PD, and their dysfunction explains many of the symptoms of the disease since these pathways are involved in different functions including motor activities, attention and learning. The motor pathway has been examined more intensively than other tracts. The model of motor pathway alteration in PD has been studied extensively for the last three decades, although some aspects of the model and the hypothesis as a whole have been challenged which have led to various modifications. According to this model, the basal ganglia normally inhibits a number of motor systems, preventing them from becoming inappropriately active. When a motivation or decision is made to perform an action, inhibitory influence is reduced for the target motor system, facilitating the activation. Dopamine has a major role in such inhibition, so high levels of dopamine can promote motor activity, whereas low levels of dopamine require greater effort for any given movement. This mechanism- dopamine depletion is the cause of hypokinesia and reduced motor output. Pharmacotherapy of PD is aimed to induce excessive dopamine activity, prevent the activation of motor systems at inappropriate times and thereby prevent dyskinesias.

Almost two centuries ago, J. Parkinson first described the disease that bears his name. There are various etiological factors in PD. Age is the most evident risk factor and the genetic predisposition second. This explains the increase in prevalence of Parkinson's disease with age. PD reduces the life expectancy and in few decades the neurodegenerative disorders will be the main cause of mortality in elderly, surpassing cancer.

Results of clinical trials showed that PD has higher incidence after the age of 50. Less than 10% of patients manifest symptoms before the age of 40<sup>[3]</sup>. On the other hand the prevalence of the disease decreases after 65 years of age and in persons over 80 is not more than 1%.

PD symptoms are classified as motor and not motor. The motor symptoms include: resting tremor, bradykinesia, muscular rigidity, and postural impairment. Non motor (non-dopaminergic) symptoms of PD are various: disorders of mood, behavior, cognition and a speech disorder characterized as hypokinetic dysarthria<sup>[4]</sup>. Sustained vowel phonation in PD is measured by the basic frequency or pitch of vocal vibration, extent of voice range variability (jitter), the extent of expiratory flow changes (shimmer), and the noise amplitude relative to normal speech tone. Voice onset time (VOT) is also used to evaluate speech in PD. VOT is the period from articulation of a stop consonant to the pronunciation the following vowel<sup>[5]</sup>. All these measures or parameters are changed in PD differently and have specific alteration pattern.

The jitter or extent of voice variation represents the variability of the speech basic frequency (characterized also as pitch period) from one cycle to the next<sup>[5]</sup>. It could be characterized also as short-term perturbations (from cycle-to-cycle) in the basic frequency of the voice<sup>[6]</sup>. The shimmer is the extent of expiratory flow variation typical for each vocal cycle. It is a cycle-to cycle, short-term fluctuations in voice amplitude<sup>[7]</sup>. Resonance is defined the selective augmentation of certain frequencies using induced vibrations in the chest, pharynx, and head sinuses<sup>[8]</sup>.

## SPEECH PARAMETERS

Articulation is one of the main parameters in speech. It is the pronunciation process of consonants and vowels, where lips, tongue, palate, and pharynx have a key role. The process is controlled by the laryngeal stops and initiation of phonation to pronounce voiced and unvoiced sounds<sup>[8]</sup>. The easiest method to analyze the articulation is the diadochokinetic (DDK) task. The DDK task analyzes the ability to repeat a combination of a consonant and a vowel (C-V combination) with both lips pursed. The patients have to pronounce keeping the tongue against back of the upper teeth (alveolar), or pronounce keeping the tongue against the soft palate (velar) in a rhythmic manner. Subjects are required to repeat three-syllable item (usually /pa/-/ta/-/ka/) as fast and long as possible.

Prosody is another parameter studied in patients with PD. It is the variation in loudness, pitch, and timing of the speech. 13 Prosodic parameters are characterized as fundamental frequency, intensity (loudness), rate of articulation, characteristics of pause, and the rhythm of speech.

Asthenia is the measure of strength of voice. It is most often measured by the subjective GRBAS scale (Grade of Dysphonia, Roughness, Breathiness, Asthenia, Strain)<sup>[9]</sup>.

## CHANGES OF SPEECH PARAMETERS IN PD

The vocal changes in PD are influenced by different factors. PD patients usually speak in a soft, monotone. This monotone speech is perceived as normal by the patients. The patients lack a feedback between speech and muscular effort from chest wall and diaphragm<sup>[8]</sup>. Parkinsonian dysarthria can affect up to 90% of patients in various stages of disease<sup>[10]</sup>.

Phonatory impairment is the primary impairment in PD and second more frequent impairment is the articulation although PD

patients usually manifest more speech abnormalities. For example, alteration of prosody is another manifestation of PD. Different components of Prosody can be altered, including speech rhythm and velocity, rate of articulation and speech to pause ratio, intensity of speech, and variation of pitch<sup>[10]</sup>. A number studies have confirmed that as the disease progresses, the voice pitch starts to decrease. Other components that are usually changed in patients are speech rate and characteristics of pause. Defects of production were revealed almost in all PD patients, including frequency reduction and fluctuations of intensity in reading tasks.

In a clinical trial PD patients (without pharmacotherapy) were compared to the group of healthy controls in voice functions (jitter, shimmer, noise to harmonics ratios (NHR)) using sustained vowel phonation. The only phonation parameter that did not show statistical significances between the study and control group was pitch variations. Patients in early stages of PD usually don't have impaired control of stationary voice pitch during sustained phonation. For all other measurements of phonation significant differences were observed between the two groups.

Voice change such as hoarseness, hypophony, and tremolo are significantly different for all types of shimmers, jitters, and NHR<sup>[5]</sup>. Another study has analyzed voice parameters compared to UPDRS scores. According to the study results roughness, breathiness, and asthenia were more expressed in patients with PD than in the controls. The obtained values were higher for both males and females with PD. Males with PD also manifested a significant increase in roughness. The authors concluded that that pathophysiological changes in PD alter the voice, but only few significant correlations were found between the UPDRS and traditional voice indices<sup>[9]</sup>.

Alterations in the auditory system and altered auditory-motor integration in PD may contribute both the perception (self-perception) of voice and correspondingly speech production in patients. An interesting study, that was focused on speech disturbances in PD, revealed differences between spontaneous or regular speech and text reading. Altered organization of speech gestures in hypokinetic dysarthria could be caused by impaired motor planning and disorganization of internal model of motor actions. This study was based on clinical observations as well as various reports that cause dysfunction in basal ganglia affecting articulation and phonation, that are expressed differently in spontaneous and repeated speech. For the spontaneous speech an internal motor plan is required with consecutive initiation, execution, and monitoring, and a template is created for repeated speech, decreasing the load on motor system of speech control<sup>[11]</sup>.

## COMPARATIVE EFFICACY OF PD TREATMENT BASED ON VOICE AND SPEECH IMPROVEMENT IN PATIENTS.

Acoustical voice analyses can provide useful information for the diagnosis of PD in different stages of the pathology, for continuous monitoring of patients, but first of all, for providing a sound feedback in voice treatment for therapists<sup>[5]</sup>.

The significant impact of task on speech motor parameters was evaluated. The task used to analyze voice disturbance must be taken into account to identify motor speech processes, and to understand the influence of brain dysfunction not only on voice, but also on articulation<sup>[11]</sup>.

A special voice therapy called Lee Silverman Voice Treatment

(LSVT) has been studied in several trials and was shown to be an effective tool for the alleviation of hypokinetic dysarthria. It affects the increased amplitude of motor output during speech production by applying increased vocal cord efforts and loudness, and in this way helps the patients to modulate their vocal output<sup>[12]</sup>. The trials have revealed statistically significant efficacy of this method on speech pathology in individuals with various stages of PD. The effects of LSVT usually last not less than 2-3 years. The obtained data showed that this methodology improves also swallowing, articulation, improves communicative gestures, neural functioning and facial expression<sup>[13]</sup>. Further efforts of researchers are aimed to develop a computer-based LSVT program which can increase the efficacy of treatment<sup>[14]</sup>.

All mentioned trials had derived some common conclusions and recommendations for the application of LSVT in patients with PD. The first conclusion stated that LSVT can yield long lasting effects on the speech of patients. The second conclusion stresses that the method targets different systems that use the same muscles and nerves to produce speech and ensure the swallowing. In this the method can result in high efficacy for voice and swallowing recovery<sup>[15]</sup>.

Deep brain stimulation of the subthalamic nucleus (DBS-STN) results in dramatical improvement of overall motor functions of the limbs. It effectively reduces tremor, but shows not stable results in speech rehabilitation. Several studies that were focuses on the efficacy of DBS in patients with PD have shown controversial results. Some of them have reported speech problems as side effects in patient receiving DBS after implantation. Others mentioned no changes in speech disturbances, and the third group has revealed an actual improvement. This diversity of results are most likely secondary, such as lesions induced by stimulating electrodes, difference in the stage of PD, different disease pattern in studied patient groups<sup>[13]</sup>.

The studies have reported also high efficacy of DBS when changing the settings of stimulation and selecting zones away from motor control centers. A number of studies emphasize the differences within an individual in the effects of stimulation on the two speech subsystems. These findings should temper global statements about the effect of neurostimulatory implants on Parkinsonian patients. They also emphasize how important careful consideration of individual differences may have on the effect of deep brain stimulation on different subsystems of speech<sup>[16]</sup>. DBS affects the respiratory and laryngeal control not similarly. High-frequency stimulation results in respiratory overactivation which results in excessive closure of vocal folds. On the contrary low frequency stimulation has more beneficial influence. According to the statement of the authors the most important aspects in the rehabilitation of PD patients are not only the difference between high- versus low-frequency stimulation, but also between speech and limb function<sup>[17]</sup>.

Electrical stimulation of the subthalamic nucleus aims to modulate the activity of the basal ganglia. The method is rather effective in the motor recovery, but in general does not affect the speech pattern. In the same way the pharmacological therapies (levodopa) are not as effective for speech as they are for motor functions.

These data underline differences in the relationship between speech and nonspeech motor control systems in PD and point out the complex input of these factors. DBS may have different effects on different components of motor speech processes in different and in some cases even in an opposite way. All these arguments make it rather difficult to compare effects of DBS on various elements of motor speech<sup>[18,19]</sup>. This difficulty is due to the complex pathogenesis of PD as the brain tissue alteration progresses on different brain structures based on their neurobiological characteristics rather than

merely increasing degeneration in a restricted neuroanatomical zone. This fact points to a possibility that degeneration alters different transmitter systems.

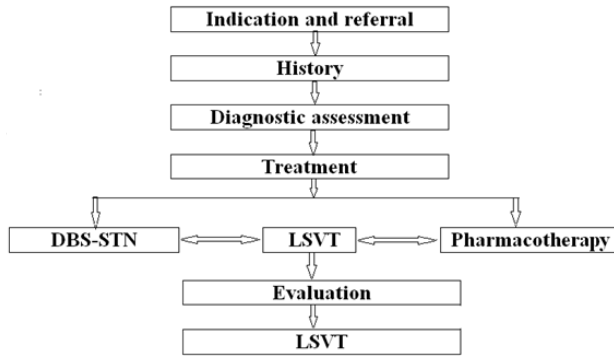
Different drug groups have been developed to treat PD. Some of these drugs potentiate (DA agonists) or substitute (L-dopa) the DA in the brain of patients with PD. Treatment options for the Parkinson's disease include: anticholinergic agents, monoamine oxidase-B (MAO-B) inhibitors, and catechol-O-methyl transferase (COMT) inhibitors<sup>[20,21]</sup>. Pharmacotherapy of PD was initiated with anticholinergic agents which have been used for years. Blocking the action of acetylcholine (ACh), they reduce tremor which is caused by the deficiency of DA<sup>[22]</sup>. Little improvement in articulation was observed after the administration of anticholinergic agents<sup>[23]</sup>. MAO-B inhibitors such as Deprenyl stop the degradation of DA and may potentiate the L-dopa action. Deprenyl has been shown to improve speech in both subjective and objective measures of articulation and respiration<sup>[24]</sup>. Articulatory improvements were observed in oral motor diadochokinesis and respiratory improvements were revealed in values of vital capacity and number of words pronounced per exhalation<sup>[24]</sup>. Though speech improvement was not found to be as significant as motor symptoms, the speech parameters were improved to a certain level by L-dopa therapy<sup>25</sup>. Patients were evaluated by an oral reading task, and speech rate, pauses, and rhythm were reported as the most improved<sup>[25]</sup>.

Other studies have studied labial kinematics and muscle physiological responses induced by L-dopa. Labial movement study revealed a shorter period of time between the initiation of labial movement and speech, and increased speed and symmetry of labial activity<sup>[26]</sup>. This showed that L-dopa normalizes the neuronal control of labial movements contributing to the speech improvements in patients with hypokinetic dysarthria<sup>[27]</sup>. More recent studies have not shown significant difference in acoustic measures. Persons with PD had lower intensity and variability of baseline frequency and intensity, and highly expressed whisperiness and harshness in PD patients compared to healthy control subjects and these data did not change after pharmacotherapy<sup>[28]</sup>.

Thus, presented strategies for the treatment of PD have different impact on speech recovery. Being a special method of speech therapy LSVT has maximum positive influence on speech recovery (Table 1). DBS-STN and pharmacotherapy result in partial recovery of speech and must be followed by such a specialized method of speech rehabilitation like LSVT (Figure 1). Various tasks have been applied evaluating the stimulability of speech in Parkinson's disease. These tasks include automatic speech tasks, maximum phonation time, maximum pitch range and loud calling. Interesting specific pattern of speech recovery has been reported by different authors. Partial recovery of speech in patients treated with DBS-STN, pharmacotherapy and LSVT are presented in the table 1.

**Table 1** Efficacy of different methods on motor and speech recovery in patients with PD.

	LSVT	DBS-STN	Pharmacotherapy
Motor recovery	--	- +	- +
Speech recovery	++	- +	- +
<b>Respiration</b>	++	- +	- +
Voice	++	- +	- +
- quality	++	- +	--
- loudness	++	- +	--
- pitch	++	- +	--
<b>Articulation</b>	++	- +	--
<b>Resonance</b>	++	- +	--
<b>Prosody</b>	++	- +	- +
- intonation	++	- +	- +
- speech rate	++	- +	- +



**Figure 1** Strategy of speech rehabilitation in patients with Parkinson's Disease.

Computer based technology helped to develop new effective solutions for the treatment of dysarthria in patients with PD. These technologies provide effective delivery of drugs, long term and high efficacy of rehabilitation<sup>[29-31]</sup>. Recent studies have shown the impact of telepractice and different software programs on treatment efficacy for LSVT LOUD<sup>[32-35]</sup>. Tindall *et al*<sup>[105]</sup> conducted a cost analysis comparing in-person effectiveness of LSVT LOUD versus the telepractice application. The in-person treatment required 51 hours for 16 visits and \$1222.00 for total expenses, whereas the telepractice method required 16 hours of time and \$970.00.

A special software program has been developed to register acoustic data and create an interactive feedback for patients treated with LSVT LOUD exercises. Telepractice and software programs will increase accessibility of LSVT method. The use of this technology is not LSVT specific and has a potential to increase accessibility, enhance effectiveness, and reduce financial burden of many intensive rehabilitation programs for people with PD.

Animal models of PD to study movement and exercise have been described and used in a large number of studies but no analogous models were developed to study vocalization deficits. Only recently new models were developed to study vocalmotor deficits following dopamine depletion in rodents and songbirds<sup>[36-38]</sup>. Effective animal models can improve our understanding of voice/speech deficits in PD and reveal the therapeutic value of these interventions to inhibit voice/speech symptom progression in patients with PD.

Future research will focus on the underlying mechanisms of treatment caused changes that have a positive impact on speech and quality of life in patients with Parkinson disease.

## OUR RESEARCH STRATEGY

Our ongoing study in LSVT and combined treatment is focused on issues related to the significance of comparing two treatment strategies: LSVT LOUD which trains vocal loudness and LSVT ARTIC which is articulation training. LSVT LOUD tries to reach the healthy level of vocal loudness using variety of speech tasks: high/low vowels, sustained vowels, speech hierarchy and functional phrases. LSVT ARTIC uses high-force articulation or pronunciation using special speech tasks: diadochokinesis and functional phrases.

Preliminary data that were obtained in one year period revealed better post-rehabilitation results in LSVT LOUD. patients in both groups were evaluated by testing the single-word intelligibility in noise conditions<sup>[39]</sup> and using the Facial Action Coding System (FACS)<sup>[40]</sup>.

Summarizing the above data that present the etiology of dysarthria in patients with Parkinson's disease, we have underlined the most

important aspect of that - the dysarthria is not purely dopaminergic, and therefore traditional pharmacotherapy or DBS for motor defects do not target the speech problems. Voice therapy can be very helpful, especially for mild to moderate cases of PD. Other methods, including electrical stimulation of the subthalamic nucleus or Deep Brain stimulation have distributed controversial results. Application of DBS or stimulation of the subthalamic nucleus requires individual approach and detailed analysis of manifestations and various radiologic examination data in patients with PD. LSVT LOUD remains as a better option for the speech therapy in patients with PD.

## CONFLICT OF INTERESTS

The authors have no conflicts of interest to declare.

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