INSTRUMENTAL AND PERCEPTUAL EVALUATION OF VOICE QUALITY IN MULTIPLE SCLEROSIS PATIENTS TREATED WITH DEEP BRAIN STIMULATION FOR INTENTION TREMOR AND UPPER LIMB ATAXIA

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ABSTRACT

Objectives: The effect of deep brain stimulation (DBS) on voice quality in 8 patients with multiple sclerosis (MS) was examined instrumentally and perceptually. **Methods:** First, vowel productions of the patients (produced with and without stimulation) and of a group of 16 healthy control speakers were analysed. Second, the acoustic signals of the same vowel productions were prepared for perceptual evaluation. **Results:** With stimulation, phonation has a greater tendency to be strained and, in comparison to the healthy control data, hyperfunctional phonation behaviour can be identified under this condition. The results of perceptual evaluation support this strained phonation behaviour under stimulation resulting in a smaller degree of breathiness ratings of all raters. Without stimulation, a higher rate of perturbation in the acoustic signal can be shown. These findings are also supported in the perceptual experiment providing a higher degree of roughness ratings of all raters for these signals. **Conclusion:** The results suggest the need for long-term monitoring of phonation behaviour during DBS in order to initiate adequate treatments without delay.

Keywords: multiple sclerosis, DBS, Acoustic analysis, perceptual evaluation of voice quality

1. INTRODUCTION

Diverse disturbances because of demyelinization as well as axon decline in disseminated areas of the central nervous system are observed in patients with MS. Symptoms like tremor of the upper extremities as well as head tremor and ataxia are frequent complications of this pathology [8]. The extremity tremor is primarily an intention tremor with a significant action and postural component. Further, phonation changes and glottal-supraglottal articulation disturbances also appear for patients as accompanying symptoms to these movement disorders. In this regard, they can show different dysarthric symptoms, e.g. in cases of cerebellar ataxia, patients may have rough voice quality with pitch and loudness perturbations and, additionally, reduced precision of articulation behaviour [9]. The symptoms often already exist before treatment, but they are also found as undesirable symptoms after DBS for particular kinds of tremor [3].

Surgery for patients with MS tremor has been aimed at the ventral intermediate nucleus (v.i.m.) of the thalamus including the subthalamic area. Stereotactic thalamotomy provides good control at first but the benefit declines over time [5]. For this reason, and also because of the excellent results obtained with chronic DBS, this neurosurgical method has been used to treat patients with MS, Parkinson’s disease and other neurological pathologies for example like distonia, essential and cerebellar tremor.

During the application of DBS, the effect on glottal phonation and on other speech subsystems has been studied in several papers, e.g. [1, 2].

The purpose of the present study is to investigate, instrumentally and perceptually, characteristics of voice quality in patients with MS treated with DBS. Consequently, the aim is to evaluate the effects of DBS itself rather than compare the preoperative and postoperative intelligibility of the patients’ phonation.

2. MATERIAL AND METHODS

2.1. Patients and control group

Eight patients were studied suffering from MS (2 males and 6 females). They were treated with high frequency electrical impulses to the left and/or right ventrolateral area of the thalamus into the v.i.m. reaching the subthalamic area as shown in

[6]. Patients exhibited a severe combined upper and lower limb, truncal and gait ataxia which could not be sufficiently suppressed pharmacologically. They were dependent on foreign aid for all activities of daily living: eating, drinking, brushing teeth, combing hair, dressing, hygienic care etc. The age of the 2 male patients was 42 and 45 years at the time of speech registration. The 6 female patients ranged in age from 37 to 45 years. Mean (sd) age was 39 (4) years.

The expanded disability status scale (EDSS score [4]) for the 2 male patients were 7.0 and 8.0. They were predominantly wheelchair bound. Two female patients had an EDSS score of 6.5 and the other 4 female patients had 7.0 (also predominantly wheelchair bound). Patients were being treated for upper limb ataxia and intention tremor and were therefore available for recording without additional inconvenience to themselves or their carers. Since upper limb ataxia and intention tremor, not speech quality, was the reason for undertaking DBS, there had been no preoperative dysarthria or voice quality classification.

Sixteen healthy subjects (8 males and 8 females) with no known speaking and hearing problems and a mean (sd) age of 38 (5) years served as control subjects.

2.2. Speech material and recording procedure

Subjects were required to produce the continuous vowels [i:], [a:] and [u:] in normal pitch. Patients produced the vowels with and without stimulation. The microphone signal was recorded in a sound-treated room, using a neckband condenser microphone (NEM 192.15, Beyerdynamic). The signal was fed directly into a Computerised Speech Lab (CSL station, model 4300B) at a sampling rate of 50 kHz. Amplitude resolution was 16 bit. For each signal, a portion of more than half a second between positive zero-crossing was selected, starting 0.5 s after the beginning of phonation.

2.3. Acoustic measurements

The signal was analysed using the Multi Dimensional Voice Program (MDVP, Kay Elemetrics model 4338).

2.4. Perceptual ratings

The 96 vowel recordings were judged over headphones in a quiet room by 10 raters (5 professional and 5 so-called naive listeners). The raters used the roughness-breathiness-hoarseness-scale (RBH-scale) [7]. The vowel stimuli were presented only once in a randomized order and were preceded and followed by 10 fillers. Each stimulus was preceded by a short beep and a 500 ms pause and followed by a silence of 10 s, during which each of the raters typed in his response.

2.5. Statistical procedures

Data analysis was performed using SPSS version 17 for all tests.

Firstly, to normalize for the gender differences the parameter-values of all measurements were expressed as z-scores.

Secondly, for each of the parameters as a dependent variable, an ANOVA was carried out for the effects of condition with and without stimulation.

Thirdly, to compare the patients' data (with and without stimulation) with the healthy control data, an ANOVA between ON and controls and OFF and controls was carried out.

Finally, in order to look at the perceptual ratings and relationships between perceptual scores and acoustic measurements ANOVAs with posthoc-tests (Scheffé alpha-adjustment) and correlations (Spearmen's rho) were carried out, respectively.

3. RESULTS

3.1. Motor disability

The upper limb ataxia and intention tremor of all patients improved as a result of the v.i.m. nucleus stimulation. These results were obtained by clinical instrumental analysis.

3.2. Instrumental evaluation of voice quality

For patients, 3 parameters (sPPQ, VTI, FTRI) show a tendency for strained phonation behaviour under stimulation. This behaviour is illustrated in figure 1 for the parameter sPPQ and in figure 2 for the parameter FTRI, respectively.

The lower values of the parameters indicate this phonatory change. A much smaller standard deviation under stimulation can also be observed for the two parameters.

Further, the phonation behaviour of the patients must be interpreted in comparison with the control group. In doing so, 3 parameter values (sAPQ, vFO, NHR) underline a tendency for hyperfunctional phonation behaviour under stimulation when they are compared with those of healthy controls. As an example, this behaviour is illustrated in figure 3 for the parameter NHR. The lower value of this parameter indicates this phonation behavior.

Figure 1: Smoothed Pitch Period Perturbation Quotient (sPPQ; $p<0.001$).

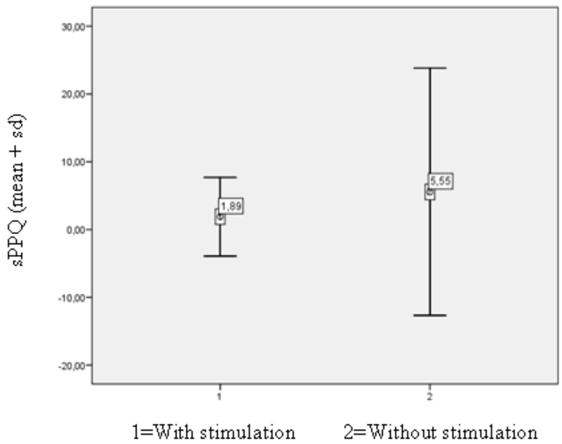


Figure 2: Frequency Tremor Intensity Index (FTRI; $p<0.001$).

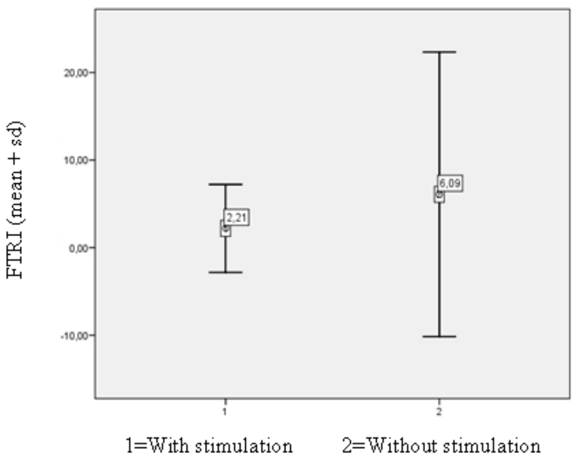
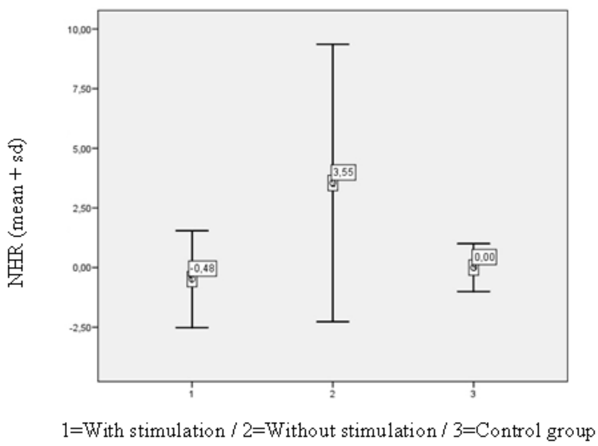


Figure 3: Noise to-Harmonic ratio (NHR; without stimulation versus control group; $p<0.001$).

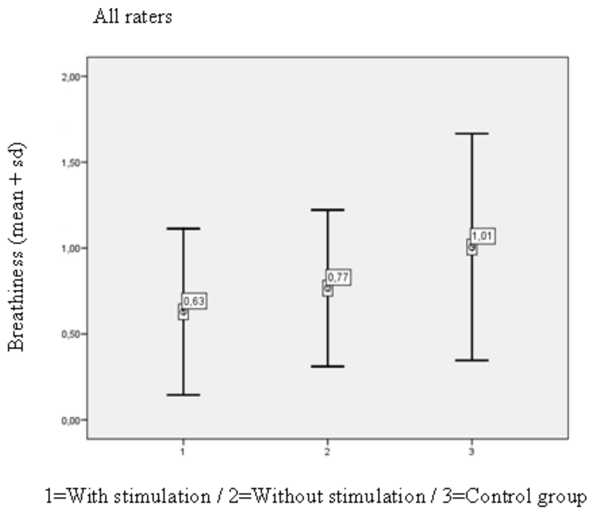


3.3. Perceptual evaluation of voice quality

Perceptual evaluation of voice quality contains two aspects: Firstly, all listener ratings of breathiness, roughness and hoarseness for the patients' stimuli produced with and without stimulation as well as for the stimuli of the control group were considered. Secondly, relationships between acoustic parameters and the degree of perceptual ratings of all listeners were taken into account.

As a result of the first aspect, the perceptual evaluation of voice quality made by all raters only shows a significant smaller degree of breathiness ratings of all raters in vowels produced under stimulation, when they are compared with healthy productions (see figure 4).

Figure 4: Degree of breathiness ratings of all raters (with stimulation versus control group; $p<0.05$).



As a result of the second aspect, the relationships between parameters indicating frequency and amplitude perturbations in the signals and the degree of roughness ratings for stimuli produced under the two conditions is shown in table 1.

It is illustrated in the table that for parameters derived from signals produced under stimulation low correlation coefficients and no significant correlations between the degree of roughness ratings of all raters and these acoustic parameters exist.

However, for parameters derived from signals produced without stimulation, only the contrary tendency can be observed. Apparently, a higher rate of perturbation in these acoustic signals leads to a higher degree of roughness ratings of all raters.

Table 1: Correlations between the degree of roughness ratings of all raters for stimuli produced with and without stimulation and frequency as well as amplitude perturbation parameters (**p<0.01).

Parameters	Roughness ratings All raters Stimuli (with Stimulation)	Roughness ratings All raters Stimuli (without stimulation)
sPPQ	0,281	0,638**
sAPQ	0,437	0,535**
vF0	0,381	0,569**
FTRI	0,141	0,576**

4. DISCUSSION

In this study, measurements from the acoustic signal and perceptual ratings were used to evaluate the effect of DBS on voice quality in MS patients treated for intention tremor and upper limb ataxia.

The patients' phonation behaviour is characterized by more strained adduction of the vocal folds under stimulation. This is instrumentally shown by lower values for the acoustic parameters and a smaller standard deviation. Furthermore, the phonation data show hyperfunctional vocal fold vibrations for patients in comparison to the healthy control data. Therefore, an increase of subglottal pressure as well as a shorter duration of closing movement can be concluded physiologically. These symptoms are typical of hyperfunctional phonation behaviour with excessive contraction of the laryngeal muscles. The diagnosis of hyperfunctional phonation can be better supported by comparing group data with the data from healthy speakers. Therefore, the necessity to examine the effect of DBS not only by comparing group means under the two conditions is demonstrated.

In connection with this kind of phonatory behaviour an impairment of upper motor neuron can be discussed pointing to the diagnosis of a type of spastic dysarthria.

The acoustically obtained results are supported by those of the perceptual experiment. Firstly, the strained phonation behaviour under stimulation leads to a smaller degree of breathiness ratings of all raters. Secondly, for frequency and amplitude disturbed signals produced without stimulation a higher degree of roughness ratings of all raters can be observed. In this way, auditory evidence of the instrumentally obtained findings is available.

5. CONCLUSION

High-frequency electrical impulses to the thalamus in patients with MS influence the phonatory behaviour of their vocal folds. The diagnosis of hyperfunctional phonation for the patients underlines the need for a long-term monitoring of phonation behaviour during chronic electrical stimulation.

However, further investigation, based on a larger number of patients suffering from MS with more or less severe dysarthria is necessary to clarify the effect of DBS on voice quality.

6. REFERENCES

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