Post Surgery Effects on VOT for Parkinson Disease STN/DBS Patients

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Abstract

In this paper we discuss and analyse voice onset time (VOT) pre and post surgical treatment with deep brain stimulation (DBS) in 17 patients diagnosed with Parkinson's disease (PD) at Sahlgrenska University Hospital in Gothenburg, Sweden. The patients were all at different stages of the disease but with the common denominator they have all undergone surgery to enhance synaptic responses through bilateral electrode implants in the subthalamic nucleus (STN) region of the brain, also known as Deep Brain Stimulation (DBS).The main focal point of the paper is to compare the pre and post surgery VOT data to see if there were any effects stemming from the STN surgery. Preliminary results for Mean VOT, Standard deviation VOT and percent of unsuccessfully produced/unmeasureable diadochokinetic syllable repetitions are presented and discussed. We found that the standard deviation decreased significantly for the consonant /p/ and this is discussed in the perspective of the ease of articulation of the different plosives.

Background and Introduction

Today there is a relatively large amount of literature on the effectiveness of surgical treatment with deep brain stimulation (DBS) to the subthalamic nucleus (STN) in Parkinson's disease (PD) patients. Several studies have documented the effectiveness of STN-DBS surgery concerning improved motor limb functions (Dromey et al., 2000), but studies investigating improvement of PD articulatory and/or phonatory speech symptoms are still small in numbers (Iulianella, 2007). The effects of deep brain stimulation of the subthalamic nucleus (STN-DBS) on speech are varied and inconclusive. Dysarthric symptoms frequently appear as side-effects and pre-existing dysarthria can be worsened. Dysarthria is reported as an adverse side effect in as many as 4-17% of patients (Benabid AL et al, 2009). The studies available on speech-related symptoms in PD in context with neurostimulatory operations show varying results in their reports where some conclude positive effects and reduced symptoms on specific motor functions, (Obeso et al., 2001) whereas others report negative effects: "With stimulation, precision of the glottal and supraglottal articulation as well as the phonatory function is reduced for some individuals, whereas for other individuals an improvement is observed." (Pützer et al., 2008). These studies emphasise the importance of individual case evaluation and substantial differences on the effects of neurostimulatory surgery on different speech functions and they are cautious determining or stating any general global effectiveness resulting from the surgical procedure. Positive reports on STN effectiveness on certain areas of speech can in some cases possibly be linked to the selection criteria itself (e.g. Gentil et al, 2003, Hoffman-Ruddy et al., 2001) where the selection of participants are made "on the basis of a significant speech impairment" (Iulianella, 2007). Apart from small patient groups, the variability in reported effects of STN-DBS on speech may be accounted for by a number of factors, including disease-specific variables, type and degree of dysarthria before surgery, and stimulation-related variables such as location of electrodes, amplitude and frequency of stimulation. Recent findings suggest that other stimulation sites may be more promising in terms of speech effects (Plaha et al., 2006).

Nearly 90% of individuals with Parkinson's disease (PD) develop speech disorders during the course of their illness but only 2–3% receive speech treatment. Speech disorders associated with PD are characterised by reduced voice volume (with a tendency for voice volume to decay over time), poor voice quality, reduced pitch variations, and reduced range of articulatory movements. Many patients also develop a tendency for speech articulation to festinate or rush as well as hesitant and/or dysfluent speech. Furthermore, PD exercises a strong influence on communication even before alterations in intelligibility or motor status become apparent.

The two main types of speech assessments, included in speech-language pathology practice, are auditory–perceptual analysis and instrumental analysis. An auditory–perceptual analysis is based on recordings and can be done blindly, but the method has questionable reliability. Instrumental analysis, e.g. acoustic analysis, is a more reliable measure and gives more precise measurements. For example, it permits measuring aspects of speech that are not yet audible or measurable in other parts of the body, and has therefore been described as a potential biomarker of early disease progression (Harel, et al. 1994).

The aim of the present project is to explore the effects of surgical treatment with DBS on a selected relevant acoustic aspect, voice onset time (VOT), defined as "…the time between the release of the oral constriction for plosive production and the onset of vocal fold vibrations…" (Özsancak et al. 2001). This aspect is thought to reflect a timing component of the motor speech process, particularly sensitive to various types of treatment.

Method

Participants

The patient group was not selected according to any specific age criteria and patient age ranges between 49-75 years. In total there are 8 men and 9 women represented. The 17 participants have all undergone bilateral subthalamic nucleus implant operations and are subject to so called deep brain stimulation.

STN-surgery

This specific operating procedure involves implanting electrodes in the subthalamic nucleus region of the brain as to enhance synaptic response. Patients are selected for surgery based on specific inclusion and exclusion criteria and are well documented pre and post surgery, regarding motor ability, cognition, depression and speech. Stimulators are turned on 1-2 days post surgery. Several post-surgical investigations are conducted, at 6 months, 1, 2, 3, 5, 7 and 10 years.

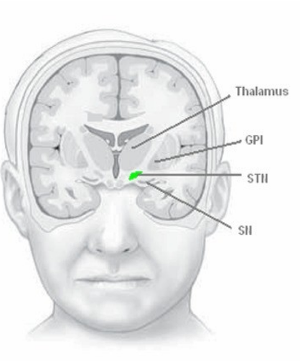

Figure 1. The surgical region of the operation.

Recordings

A majority of the recordings have been conducted at somewhat set times after surgery, 6 months, 1 year and 3 years post operation. There are however post-operation recording material for some participants dating as far as up to ten years, but the emphasis will be put on discussing the post-operative data nearest in time to the surgery.

The material investigated here are syllable repetitions, both SMR (sequential motion rates, i.e. papapapa) and AMR (alternating motion rates, i.e. patakapataka). The participants were asked to:

1. Repeat the individual nonsense syllables /pa/, /ta/ and /ka/ as fast and steadily as they can, i.e. /papapa/, /tatata/ and /kakaka/…

2. Repeat the above mentioned nonsense syllables in a given sequential order, /pataka/, as fast and steadily as they can, i.e. /patakapatakapataka…/

This test is well established in clinical work among speech-language pathologists, referred to and known as a diadochokinetic test for assessing speech.

Having digitalised the original recordings from DAT- and CD-recordings with the software Audacity to an uncompressed format (wave PCM mono) we measured Voice Onset Time (VOT) for each of the produced nonsense repetitions in the different recordings. This was done by using Praat software (Boersma and Weenink, 2009) where the designated syllable repetitions were segmented using Praat TextGrid together with a wideband spectrogram and an oscillogram to carefully study the onset of voicing. The procedure employed for the measuring of VOT was done in accordance with Lisker and Abramson's recommendations, i.e. from the initial burst of the release of the plosive to the first noticeable and regularly occuring period relating to the vocal fold onset vibration. (Lisker L, Abramson AS, 1964).

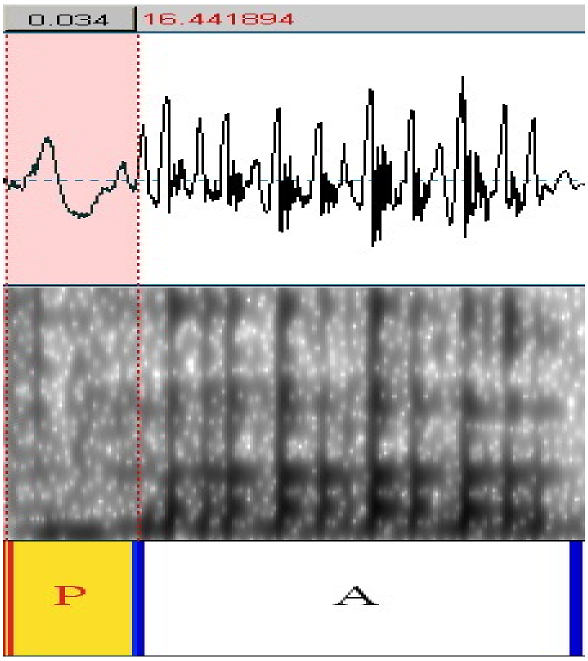

Figure 2. Illustration of VOT measurement.

When the segmentation process had been concluded, time values for VOT, calculated mean and standard deviation per consonant and recording were extracted using a Praat script. The following step included analysing the results to evaluate mean VOT, standard deviation VOT and percent unsuccessfully produced (or unmeasurable) syllables.

Measuring

In some cases the measuring of the initial burst had to be reduced to detecting visual patterns in the sound wave itself, i.e. they were inaudible bursts and had to be established visually by determining a starting point for the burst. This was achieved by looking at the energy levels in the spectrogram as well as by identifying any waveform anomalies or deviations from an expected pattern in the signal. These anomalies were then traced by the aid of the preceding utterances to find any systematic regularities occurring in the speech signal. In several other cases, as anticipated, there were problems with continuous voicing. The patient fails to realise the occlusion of the intended consonant whereby the voicing is maintained throughout the entire SMR- and AMR syllable repetition sequence. In many of these cases the only measurable initial burst was found in the very first of the many CV-segments or when the patient paused to breathe in between segments.

Another problem in relation to measurement issues for [t] was that there were some instances where the patient failed to realise the [t] and instead produced the voiceless apiko dental fricative [θ]. In these instances it was decided to exclude aforementioned segments due to lack of initial burst and also because the intended target sound was ill realised. In some cases of the production of [k] there was a pre-sequence of [x] before the realisation of the explosion itself in which case the measurement was still included, starting from the explosion as intended, ie. the pre-frication was simply ignored. In yet another case it was difficult figuring out if the actual plosive was bilabial or dental as the patient failed to produce the sequential utterance in the right order. Most of the times the patient fell towards producing [t] instead of the intended [p] or [k], which made it extremely hard to determine whether this particular instance, together with it being ill pronounced, was a [p] or [t]. The intended sound however was [p] why the instance was excluded. An interesting observation in another case was when the subject was to repeat the SMR /ta/-repetition and it was done at such a rate that the aural impression was that the target sound requirements were met. However, looking closer at the individual instances it was obvious that the [t] was really produced as an [s]. The rate at which the repetitions were made was so high that on a perceptual level it seemed like the target sound was realised but closer inspection showed that the [t] really lacked an initial burst, making it immeasurable.

Hypotheses

The question for this preliminary study was to investigate whether the surgery itself had an obvious effect on VOT. To get an overview of the data, a fit between VOT mean and time was made in order to represent the progressivity of the disease. This fit included the entirety of data for all consonants and syllable repetitions, both SMR and AMR.

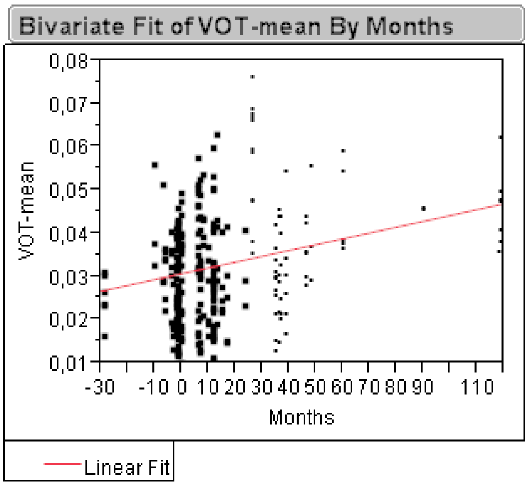

Figure 3. Progressivity of mean VOT (Y) by Months (X).

The figure shows an increase in mean VOT as a general effect of the disease. This gives us a general hypothesis on the development of speech symptoms in this progressive disorder. We can now further create the hypothesis that if the surgery has a positive effect on the VOT, the mean or standard deviation of the VOT should decrease. As we currently have no control group we cannot predict the general progressive increase in mean and standard deviation for VOT for Parkinson patients that have not been subjects for the surgery described here.

Results

Before presenting the following data we wish to point out that the results are preliminary and that the material will be subject to further studies including more detailed analyses.

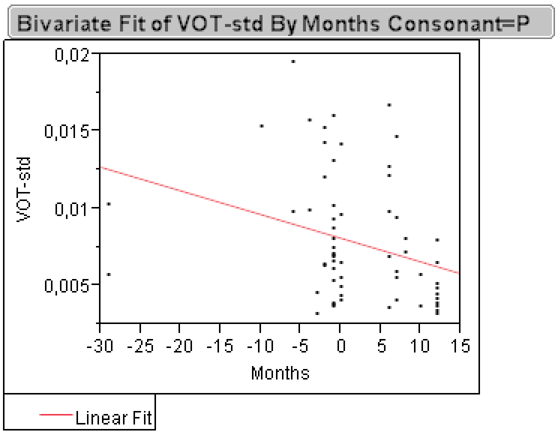

Figure 4. Bivariate fit of VOT standard deviation for /p/ one year post operation.

The figure shows the development of VOT standard deviation for the consonant /p/ calculated post-operatively over one year. VOT standard deviation shows a significant decrease (<0.05) with an explanation value of approximately 9% over the twelve month period post surgery. Apart from the significant decrease represented above in Figure 4 we could see that VOT mean for /p/ also showed a decrease although without any significant explanation value. In contrast, a slight increase for the percentage of unsuccessful productions of /p/ could be seen but similar to VOT mean without any significant changes.

Bivariate fit of VOT mean, VOT std and percent unsuccessful production of /t/ and /k/ one year post operation showed no significant changes. There was however a slight increase for VOT mean and a slight decrease for VOT standard deviation and there was also a noticeable drop in percentage of unsuccessful productions of the consonant /t/. For /k/ we saw an increase in VOT mean and VOT standard deviation but the percentage of unsuccessful productions of /k/ showed a decrease.

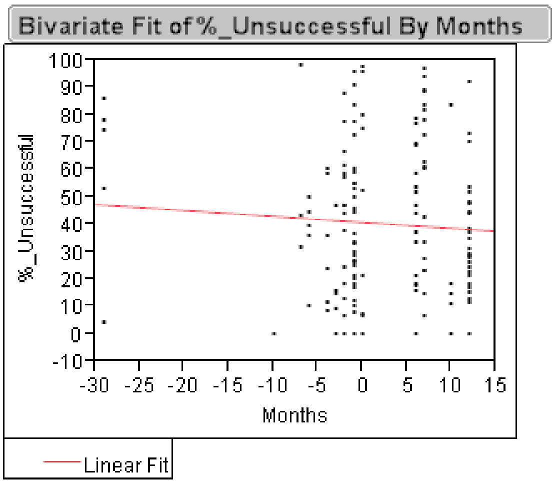

Figure 5. Development of % unsuccessful SMR and AMR syllable productions for the first post-operative year.

The figure shows a decrease in percentage of unsuccessful or unmeasurable SMR and AMR syllable repetitions calculated for the first twelve months after the surgical treatment. The percentage of unsuccessfully produced (or unmeasureable) bursts remain more or less on the same level. No significant changes were discovered post-surgically.

Discussion

These preliminary results seem to point towards no obvious significant effects for the first post-operative year other than a VOT standard deviation decrease for the production of /p/. This seems to correlate well with our hypothesis of a decrease. The fact that the STN/DBS treatment seems to have a significant positive effect on VOT standard deviation for the production of /p/ can be explained by the place of articulation. It is plausible to argue that the articulatory motor functions are affected in some ways positively as in the case of improved motor limb control. Perhaps not to the same degree as motor limb movements, however, speech production requires and is dependent on more fine-tuned and detailed muscular control such as tongue movements. In the light of this it seems reasonable to assume that the bilabial movement would be easier to articulate than /t/ or /k/ where more precise articulatory movements involving the tongue tip are included. Hence we would likely see the positive effects of STN surgery through decreased standard deviation, especially for /p/.

Conclusions

These findings suggest that there should be a decrease in VOT standard deviation for /p/ resulting from STN neurosurgical operation. However, no other significant changes were observed.

Future work

It is important to bear in mind the individual differences for PD patients' varying speech symptoms, which will be further addressed and looked into in future studies. It is also imperative we look at this data on an individual level, including such variables as patient history, age, gender and soforth. Besides looking deeper into the here employed conventional VOT measurement, it would also be beneficial to include VOT ratio measurements in future studies, i.e. where the effect of rate is removed (Fischer et al., 2010). These things combined will no doubt present us with a more detailed and descriptive view of the effectiveness of neurostimulatory STN surgery on VOT for patients with Parkinson's disease.

Acknowledgements

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