

Perceptual and Acoustical Assessments on Spasmodic Dysphonia: Pre and Post - Botulinum Toxin Injection

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Abstract

Adductor spasmodic dysphonia is a vocal disorder of uncertain etiology with no satisfactory long-term treatment-result. Recently injection of Botulinum toxin (BOTOX) into the thyroarytenoid muscle has been used as an effective temporary treatment. In this experiment, 9 patients with adductor spasmodic dysphonia (SPD) were studied and injected percutaneously the Botulinum toxin with dose of injection ranges from 1.25 to 5 units totally. Post treatment results were monitored acoustically for objective voice analysis and auditorily for perceptual judgment. Temporary satisfactory results were obtained after the average of 2 months post-injection, and lasted for at least 5 months of average. The test of vocal controllability derived from several acoustic parameters extraction, e.g. the pitch perturbation quotient (PPQ), amplitude perturbation quotient (APQ), the Fo overall variability (FoV), energy of slow and fast Fo perturbation (FoS and FoF), showed improvement on post-BOTOX injection, and illustrate the efficacy of the analysis system used.

Abstrak

Disfonia adduktor spasmodik adalah kelainan suara yang etiologinya belum jelas, dengan hasil terapi jangka panjang yang tidak memuaskan. Dewasa ini injeksi toksin Botulinum (BOTOX) ke muskulus tiroaritenoid banyak diterapkan. Pada penelitian ini dilakukan studi pada 9 kasus disfonia adduktor spasmodik dengan menyuntikkan 1.25 sampai 5 unit BOTOX melalui kulit ke dalam otot laring. Hasil terapi dimonitor secara akustik untuk menganalisis suara secara objektif dan perseptual. Keberhasilan sementara didapatkan setelah kurang lebih 2 bulan pasca terapi, dan berlanjut sampai kurang-lebih 5 bulan. Tes kontrol suara yang dihimpun dari hasil beberapa parameter yang dihitung yaitu: pitch perturbation quotient (PPQ), amplitude perturbation quotient (APQ), Fo overall variability (FoV), energy of slow and fast perturbation (FoS and FoF) menunjukkan perbaikan yang bermakna pada grup pasca-BOTOX. Hal ini juga menggambarkan kinerja yang berdaya-guna dari sistem analisis suara yang dipakai.

Keywords: spastic dysphonia, voice analysis, vocal controllability.

Spasmodic dysphonia (SPD) is a central nervous system phenomenon of unknown etiology characterized by uncoordinated voice tremor with erratic patterns of laryngeal contraction.¹

The uncertainty of the SPD etiology arose researchers to conduct experiments and options in the treatment of SPD patients to try to eliminate the disruptive voice symptoms. Such attempts were resection of a portion of the reccurent laryngeal nerve on one side,² CO₂ laser resection of the thyroarytenoic,³ anterior laryngoplasty, voice therapy, pharmacotherapy, and the most promising one is Botulinum toxin injection.

Eventhough most of opinions declared that adductor SPD was a vocal disorder with no satisfactory long-term treatment-result, many experiments had been

conducted. Woodson et al⁴ reported a study on the effects of Botulinum toxin therapy in patients with adductor SPD in term of acoustic, aerodynamic and videoendoscopy findings, and concluded a successful result on post-therapy condition. Adams et al⁵ reported a study concerning unilateral versus bilateral Botulinum toxin injections in SPD for acoustic and perceptual results and concluded that unilateral BOTOX injections may provide both superior and longer lasting benefits than bilateral BOTOX injections. Green et al⁶ reported his method of point-touch technique of Botulinum toxin injection for the treatment of SPD by means of flexible nasopharyngeal endoscopy guidance. Kobayasi et al⁷ also reported his successful method for percutaneous insertion technique of the needle for injecting the Botulinum toxin into the thyroarytenoid muscle of SPD patients.

Botulinum toxin is produced by the anaerobic bacterium *Clostridium botulinum*, and causes temporary paralysis by blocking the presynaptic release of acetyl-

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choline at the neuromuscular junction. This action is clinically used to alleviate muscle spasm by injecting the toxin directly into the overactive muscle.

Despite so many experiments and researches has been done concerning SPD, there are still many unanswered questions, and the field for investigations and researches in SPD remains widely open.

In this study, experiment was conducted upon adductor SPD patients, and injection of Botulinum toxin was performed using percutaneous technique of needle insertion into the thyroarytenoid muscle. Auditory perceptual were done subjectively by the patients themselves and objectively by the doctor. Besides, acoustical analysis were also performed before and after treatment, to monitor the results as a follow up mean.

MATERIALS AND METHOD

This study was conducted in the Research Institute of Logopedics and Phoniatics (RILP), Tokyo University, from 1995 through 1996. The subjects for this experiment were 9 patients of adductor SPD, consisted of 2 males and 7 females with ages ranged from 20 to 71 years, who had been suffering from the disease for more than six months. The control group voice samples were obtained from 15 normal speakers aged 26 to 67 years. The normal/healthy voices were the modal voice samples produced at most comfortable level and pitch by healthy speakers, without any history of pathology affecting phonation.

BOTOX injection were performed using percutaneous procedure, and the technique is identical to electromyography of the vocal folds. A 23-gauge hypodermic needle, coated with Teflon except for its tip, was used both as a monopolar electrode to locate the vocal folds and as an injection channel. The needle was inserted percutaneously through the cryothyroid membrane, and correct positioning of the needle was confirmed by EMG display or audiomonitoring on phonation.

Voice samples collection were performed by recording sustained vowel /a/ produced by subjects as long as they were able to, at their most comfortable level and pitch. SPD voice samples were obtained before (pre-BOTOX) and about 2 months after (post-BOTOX) BOTOX injection.

Recordings were made using DAT tape-recorder, with a constant distance of 15 cm, between microphone and

mouth, following repeated patient's practice, and recordings were made in sound attenuated room. Voice samples of sustained vowel /a/ were then digitalized through a 16-bit A/D converter at a sampling rate of 40 kHz and stored on a disk controlled by computer. The acoustic feature of a voice sample was analyzed using the "SONG" computer aided program.

Using waveform matching and peak picking method, the method proposed by Imaizumi et al,^{8,9} local maximum points which could correspond to vocal excitation epochs were detected successively and then two time series of Fo(i) and A(i), the fundamental frequency and the maximum amplitude of i-th glottal period were determined. Cycle-by-cycle perturbation quotient were calculated, pitch perturbation quotient (PPQ) and amplitude perturbation quotient (APQ) and several voice properties were extracted such as the overall variability of Fo (FoV), the additive noise level (Noise Level), and the energy of slow and fast Fo perturbations (FoS and FoF).

Two kinds of scoring were applied to assess the voice condition auditorily: appraisalment by the patients themselves depending on their feeling, called as "subjective scaling". The scores ranged between 0 (for no complaints on phonation, no difficulty, smooth, the voice seemed regular and not disruptive), up to 3 [for difficult feeling on phonation, straining, and no change compared to before injection (pre-BOTOX)]. In between there were better conditions of voices, score 1 (much better than before injection) and 2 (better than before).

The "perceptual objective scaling" was a scoring method performed by the doctor using 25 morae. The score depends upon how many morae could be well pronounced by the patients. Scaling ranged between 25 for bad condition with no mora pronounced clearly, smoothly, regularly and without voice stops, up to 0 for normal condition, the whole 25 morae were pronounced smoothly, effortless and without voice stops.

For statistical calculation, an analysis of variance (ANOVA) with one factor, the group, was performed to determined significance.

RESULTS

The acoustic feature of a voice sample analyzed using the "SONG" computer aided program was consisted of 5 panels and showed on figure 1.

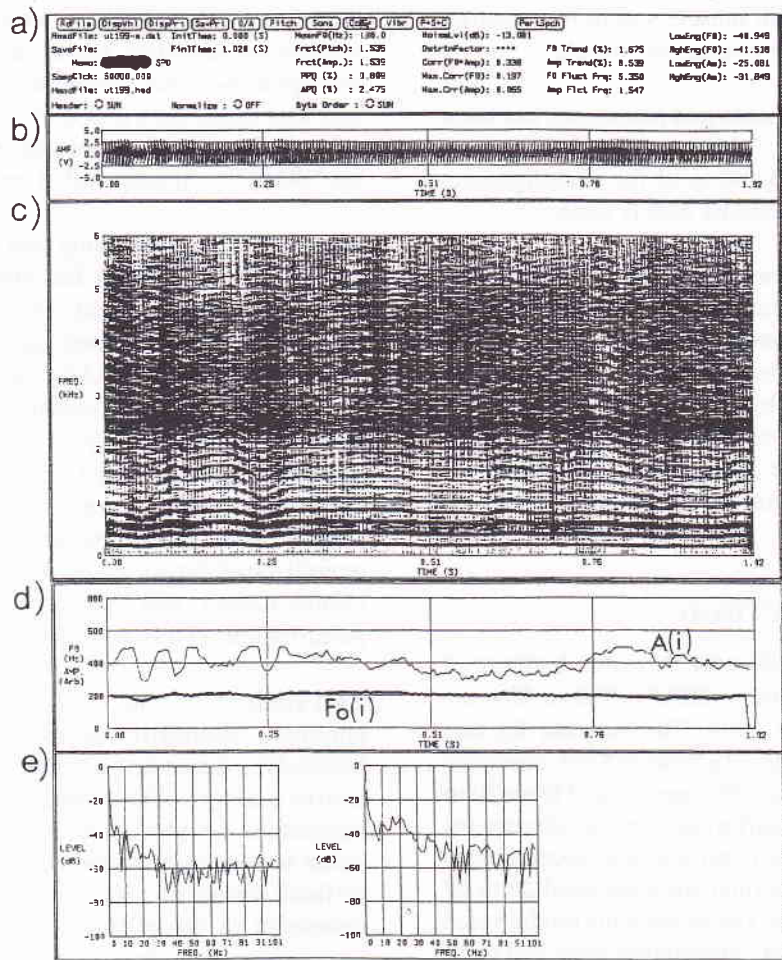


Figure 1. The acoustic feature of a voice sample analyzed by "SONG" computer-aided program. a) display of analysis conditions and results, b) the voice waveform, c) the sound spectrogram, d) F_0 and amplitude time series calculated using the acoustic analysis, e) the power spectrum of $F_0(i)$ and $A(i)$.

The bar plot of the Log10 pitch perturbation quotient (PPQ) for the whole groups was showed in figure 2. The mean value of PPQ before injection was -0.061 (SD 0.718). This mean value was decreased to -0.533 (SD. 0.331) after injection, but the normal control group had the lowest mean value (-0.897 , SD 0.246). Statistical analysis showed that post-BOTOX injection the PPQ was decreased significantly ($P < 0.0001$), but still higher compared to normal voices.

The bar plot of Log10 amplitude perturbation quotient (APQ), for the whole groups was showed in figure 3. After injection, the APQ (mean value 0.379, SD 0.379) was unsignificantly decreased ($P > 0.005$) compared to before injection (mean value 0.401, SD 0.374). However, compared to the normal control (mean 0.142, SD 0.246) the difference is significant ($P < 0.0001$).

Figure 4 showed the bar plot of the overall variability of F_0 (F_0V), indicating that after injection of BOTOX the F_0V (mean value 2.839, SD 5.685) was decreased significantly ($P < 0.0001$) compared to before injection (mean value 19.870, SD 25.878), but still larger compared to normal voices (mean 0.830, SD 0.467).

Figure 5 showed the bar plot of the energy of slow F_0 perturbation (F_0S), revealing the significant decrease ($P < 0.0001$) in the strength of F_0S on post-BOTOX injection (mean value -42.560 , SD 8.772) compared to pre-BOTOX injection (mean value -32.200 , SD 16.775), but still stronger compared to normal group (mean -46.503 , SD 4.393).

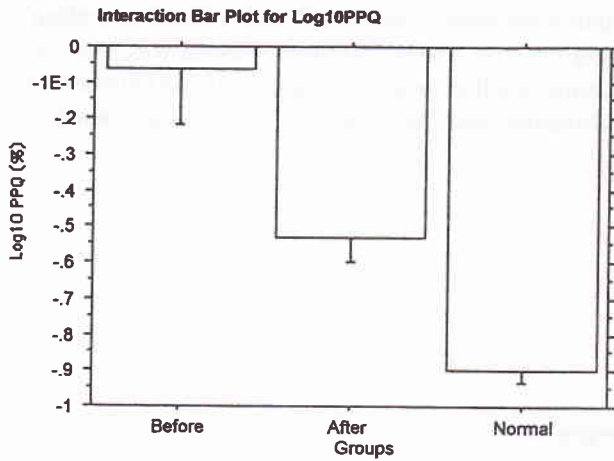


Figure 2. The bar plot of Log 10 pitch perturbation quotient (PPQ) for the whole groups.

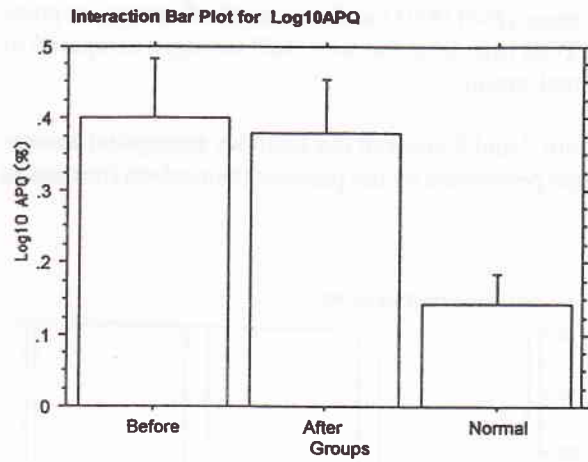


Figure 3. The bar plot of Log 10 APQ for the whole groups.

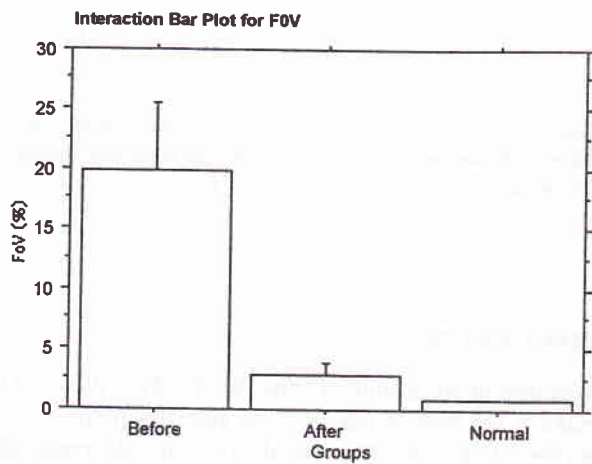


Figure 4. The bar plot of the overall variability of F_0 (FoV) for the whole groups.

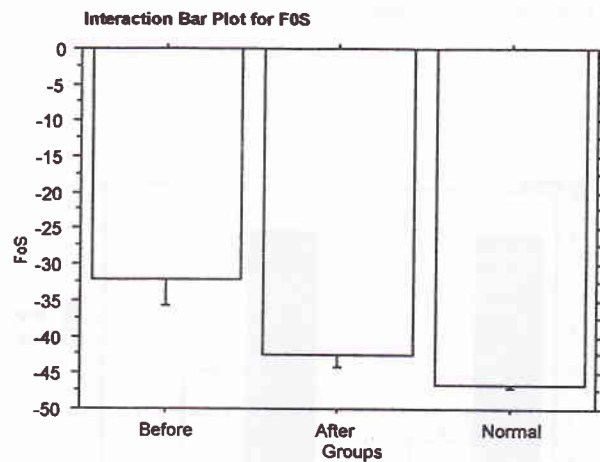


Figure 5. The bar plot of the energy of Slow F_0 Perturbation (FoS) for the whole groups.

Figure 6 showed the bar plot of the energy of fast F_0 perturbations (F_0F). The mean F_0F value of pre-BOTOX injection was -39.140 (SD 17.674). This was -49.171 (SD 7.062) in post-BOTOX, and -56.689 (SD 4.667) in normal control indicating the significant decrease ($P < 0.0001$) in the strength of energy on post-BOTOX injection, but were still stronger compared to normal group.

Figure 7 and 8 showed the auditory perceptual assessments performed by the patients themselves (termed as

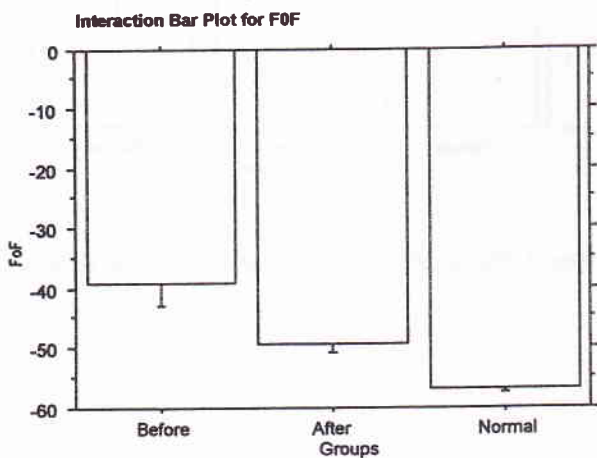


Figure 6. The bar plot of the energy of fast F_0 perturbation (F_0F) for the whole groups.

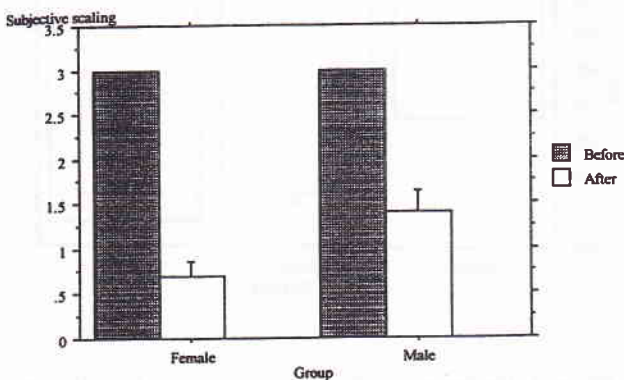


Figure 7. The bar plot of perceptual "Subjective scaling" of voice condition performed by male and female SPD patients themselves, before and after BOTOX injection.

the "subjective perceptual scaling") and by the doctor (termed as "objective perceptual scaling"). Statistically, the scores on post-BOTOX injection were significantly decreased ($P < 0.0001$) compared to the scores on pre-BOTOX injection. Moreover, the correlation between "subjective" and "objective scaling" using Pearson's 95% confident interval was 91%, indicating that there was a strong correlation between the "subjective" and the "objective" perceptual scaling.

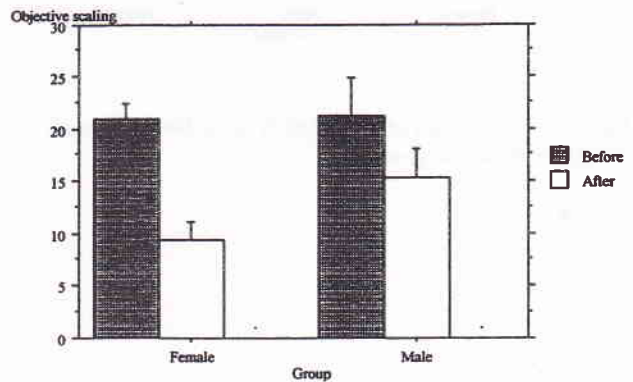


Figure 8. The bar plot of perceptual "Objective scaling" of voice condition performed by the doctor on male and female SPD patients, before and after BOTOX injection.

DISCUSSION

Injection of Botulinum Toxin (BOTOX) is directed to make a temporary paralysis or paresis of the thyroarytenoid muscle. The paralysis will decrease the muscular spasm that causes uncontrolled muscular contraction on phonation, and resulted in better condition for vibration. The situation was clearly seen in the compared results of analyzed voice samples of pre-BOTOX versus post-BOTOX injections, by assessing the voice conditions acoustically and perceptually. Temporary satisfactory results were obtained after the average of 2 months, and lasted for at least 5 months.

From the results obtained, it can be seen that all the parameters of voice perturbations extracted e.g.: the pitch perturbation quotient, the amplitude perturbation quotient, the overall variability of F_0 , the energy of slow perturbation of F_0 and the energy of fast perturbation of F_0 showed a decrease in post-BOTOX voices, indicating that post-BOTOX patients had better F_0 control compared to Pre-Botox patients, and the voices were less fluctuating and more stable. In other words, post-BOTOX patients had better vocal controllability than pre-BOTOX. The results were in accordance to other experts' reports e.g. Zwirner et al.,¹⁰ and Woodson et al.⁴ They found similar tendencies on post-BOTOX condition, although they did not compare with Normal speakers.

The APQ was not significantly decreased on post-BOTOX, this phenomenon was probably due to several reasons: the SPD subjects were mostly consisted of female patients (7 out of 9 speakers), and the female patients have a tendency to produce higher frequency and intensity on sustained vowel phonation. This condition will be resulting in reduced perturbations.

Although Post-BOTOX patients regained their voices, but compared to normal speakers, their voices have larger perturbations.

Subjective feeling and perceptual assessments of SPD voices which were performed both by the patients themselves as "subjective scaling" and by the doctor as "objective scaling", showed that on post-BOTOX the voice conditions were better and the scaling decreased significantly. Correlation calculation (Pearson's) between those 2 scalings showed strong correlation ($=0.906$), suggested that those two assessments were parallel.

CONCLUSION

1. Post-BOTOX voice samples showed a decrease in F_0 perturbations, suggested that post-BOTOX group had better vocal controllability compared to pre-BOTOX group.
2. Although post-BOTOX group regained their voices, their perturbations were higher than normal voices, indicating that compared to normal voices the vocal controllability is lower.
3. The "subjective scale" and "objective scale" were decreased significantly on post-BOTOX group,

and the two scoring scales were strongly correlated. This suggested that not only acoustically the post BOTOX group was improved, but perceptually as well.

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