Acoustic and High-Speed Digital Imaging Based Analysis of Pathological Voice Contributions to Better Understanding and Differential Diagnosis of Neurological Dysphonias and of Mimicking Phonatory Disorders

Krzysztof Izdebski1 2, Yuling Yan2 3, Melda Kunduk4

1Pacific Voice and Speech Foundation, San Francisco, CA, USA
2Department of Otolaryngology/Head & Neck Surgery, Stanford Voice & Swallowing Center, Stanford University School of Medicine, Stanford, CA, USA
3Department of Bioengineering, Santa Clara University, Santa Clara, CA, USA
4Department of Communication Sciences and Disorders, Louisiana State University, Baton Rouge, LA, USA
yanmarriott@gmail.com, kizdebski@pvsf.org, mkunduk@lsu.edu

Abstract

Using Nyquist-plots definitions and HSDI-based analyses of the acoustic and visual data base of similarly sounding disordered neurologically driven pathological phonations, we categorized these signals and provided an in-depth explanation of how these sounds differ, and how these sounds are generated at the glottic level. Combined evaluations based on modern technology strengthened our knowledge and improved objective guidelines on how to approach clinical diagnosis by ear, significantly aiding the process of differential diagnosis of complex pathological voice qualities in nonlaboratory settings.

Index Terms: HSDI, Nyquist-plots, voice quality, tremor overpressure, vocal arrests, neurologic dysphonias, functional dysphonias, mimicking disorders

1. Introduction

Clinical diagnosis and assessment of voice characteristics in neurological voice disorders may be cumbersome and often may be quite challenging, because vocal and visual signals in these disorders are unstable or complex, and because sounds generated often overlap or form a very narrow psychoacoustic grid, even between unrelated etiologies [1], making clinical diagnosis by ear a difficult task, even by clinicians with so-called expert experience. For example, vocal tremor in severe cases may produce complete voice arrests at the rate of 4-6 Hz, which is similar to vocal arrests in adductor spasmodic dysphonia [2]. Vocal tremor may also be a part of the underlying dystonia syndrome or may be mixed with other signal characteristics, e.g. overpressure [4], or it may represent itself in different forms as a function of the underlying tremor etiologies [1].

Moreover, certain movement voice disorders may be phonometrically and perceptually close to non-movement voice disorders, mimicking or masquerading as true dystonia or as true cerebellar or CNS dysphonias, as these voices may contain vocal arrests, shaking and/or overpressure [1], [5]. Also, the use of compensatory strategies by patients complicates factors in differential diagnosis. Although in clinical academic settings differential diagnosis may be conducted by time-consuming objective measures, using sophisticated technology, reality is quite different in the outlying areas, where diagnosis is mainly done by ear and not always by so-called experts. However, even in cases of expert opinions, disagreements as to what is what, are known to prevail. For example, one study reporting the diagnostic ability of expert judges vs. non-expert judges, showed a low percentage of agreement regarding such voice symptoms as voice breaks and/or vocal tremor [5].

This scenario may be specifically prevalent in the process of making differential diagnosis of so-called phonatory movement disorders that include various types of vocal tremors, spasmodic dysphonias, vocal fold paralysis (vs. vocal cord fixation), etc., as these conditions may produce voice qualities that contrast poorly against mimicking disorders, specifically in the absence of visible vocal cord pathologies, a typical situation in non-paralytic neurological voice disorders [1]. Of course, this introduces risks of misdiagnosis, and hence retards eventual treatment course [3], [1]. To improve on this dilemma, clinicians in academic settings may employ objective measures, preferably in tandem, i.e. acoustics and visualization [1], [6], but this is not a case in the outlying clinical offices. Therefore, we believe that gaining objective validity via instrumental analysis and correlating these findings with psychometric subjective measures is of paramount value to the clinical world. Consequently, we began to conduct a series of studies that utilize modern technology to investigate in-depth pathological phonation. This process was recently outlined (Sept, 2007) during our XVI Annual Pacific Voice Conference that focused this time on Technology and Pathologic Vocalizations.

This noble aim, however, presents formidable challenges. First, to understand better the nature of such compounded signals, technological improvements are needed beyond the more traditional acoustic and stroboscopic analyses. HSDI technology, though cumbersome, seems to be promising. Better results are also reported when acoustic and visual analysis are co-employed [6].

Here, we report on our investigation of neurologically-driven movement dysphonia phonation research progress, using Nyquist-plots applications of acoustic analysis and a new analytic platform for objectivization of high-speed laryngeal imaging. We demonstrate that these analyses improve differential diagnosis of phonatory disorders and in some cases will be predictive of vocal functions recovery.
To follow this reasoning, we analyzed complex acoustic signals recorded from patients with various forms of voice disorders: tremor (essential tremor, tremor in PD), SD-tremor, and mimicking disorders by carrying out combined analysis of various acoustic and image-based recordings. We used technology described elsewhere [7], [9], namely Nyquist-plots and HSDI processing based on tracing of vocal-fold edge and generation of glottal waveforms and vocal-fold vibratory displacement patterns.

2. Discussion

To achieve these goals, we acquired acoustic and high-speed digital imaging recordings of vocalizations from patients representing Adductor Spasmodic Dysphonia, Vocal Tremor, Parkinson's Syndrome phonation, Vocal Cord Paralysis, and mimicking disorders including Muscular Tension Dysphonia. We analyzed these signals using a newly developed quantitative analysis system for acoustic signals [7], [8], [9] that are based on Nyquist-plots and included HSDI processing based on tracing of vocal-fold edge and generation of glottal waveforms and vocal-fold vibratory displacements [8], allowing us to define new quantitative measures of symmetry and synchronization of vocal-fold vibrations. The aim was to aid our understanding of how disordered phonation differentiates between these different clinical entities, and how this newly acquired knowledge can be used in clinical settings to enhance clinical confidence in diagnosis of phonatory disorders by the ear alone [1].

2.1. Essential Voice Tremor

Vocal tremor is characterized by periodic involuntary oscillations that may affect any and all of the muscles which are involved in sound production, causing rhythmic changes in the voice pitch and loudness at a regular rate [1], [2], [3]. Vocal tremor is best verified during sustained phonation and its rate is essentially constant and independent of the vocal task at a rate of 4-6 Hz causing both frequency and intensity modulations. Significant irregularity and perturbation of vibration are present in essential tremor.

2.2. Tremor in PD Voice

Approximately 75-90% of individuals with Parkinsons disease have voice disorders at some time in the course of the disease. Previous investigations based on visual, perceptual, stroboscopic, EGG and acoustic techniques demonstrated that close to 55% of PD patients have incidence of vocal tremor. There is a close association between vocal tremor and PD, although the relationship is evident at a late stage of the disease. Most of the parameters derived from acoustic analyses were not affected by the severity of PD or did not change with the progression of the condition. Fastest rhythmic variation (at ~ 7 Hz) were found in PD-tremor, with moderate perturbation in intensity. Tremor-ADDS and ADDS exhibits voice breakage concomitant with rhythmic variation in amplitude. Pitch is passively affected.

2.3. Tremor/Vocal Arrests in ADDSD

Pure ADDS and vocal arrests at the rate of 5-6 Hz. Arrests are frequency specific and essentially limited to the first 1-1.5 octaves. It is difficult to distinguish coexisting tremor from ADDSD arrests unless chemical block is used [3] Overpressed voice quality in ADSD is associated with decreased open quotient.

2.4. Mimicking Dysphonia

More irregularities in acoustic pattern are exhibited in this condition, than in any other tremor-like condition.

2.5. Diplophonia MTD

Segmental vocal fold variation in anterior and posterior demotions and contribution of ventricular folds are present.

3. Conclusions

We suggest that the objective analyses of HSDI recordings combined with acoustic signal analysis from the same patients demonstrated significant improvement in our understanding of how disordered phonation is produced, perceived, and how it can be subcategorized as to construct an improved phonometric platform to establish a more comprehensive clinical diagnosis. Irregular closure pattern, rhythmic variation in frequency and amplitude (at ~ 4-6 Hz) is present in all types of phonation.

Our data support earlier observations that combined visual and acoustic analysis of disordered phonation yields superior results in contrast to a single module approach [6]. Future work will focus on examining predictable values of these analyses to the process of prognosticating both the timeframe of recovery and/or natural progression of these phonatory disorders. Information derived from these studies contribute to a more accurate diagnosis by ear.

4. Acknowledgements

Supported by NSF (BS 0402439) awarded to Dr. Yuling Yan and by the research funds from the Pacific Voice and Speech Foundation, San Francisco, CA, USA.

5. References


