Chapter 9
The impact of senescence on vocal folds kinematics in normal subjects

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Abstract

Here we provide examples of how Nyqist plot analysis accounts for the changes in vocal fold (VF) kinematics of normal subjects who are undergoing senescence.

Keywords: *HSDP, Nyquist plots, VF, senescence, GAW, displacement, asymmetry, jitter, shimmer*

Introduction

Senescence is a natural process of growing old. This involves accumulative changes to our molecular and cellular structures that disrupt metabolism and eventually result in deterioration of our functions leading to death. Senescence can involve the entire organism (organismal senescence) or only individual cells (cellular senescence). Some theories of senescence implicate gene expression changes while others blame the cumulative damage on biological processes. Whether senescence can be slowed down, halted, or even reversed, is a subject of current scientific speculation and research. Senescence also affects the voice generating apparatus, albeit differentially for gender and ethnic mix. Interestingly, we judge the voice of singers to be at least 10 years younger than the voice of non-singers. What accounts for that is unclear [1].

In these preliminary studies, we used HSDP to record VF kinematics during sustained phonation of /i/ in more than 50 normal adults across gender and age. These recordings were analyzed using our Nyquist plot approach as detailed in Yan et al. [2-6]. We categorized the Nyquist patterns for these subjects into four distinct classes (Patterns I, II, III & IV) as shown in Figure 1.

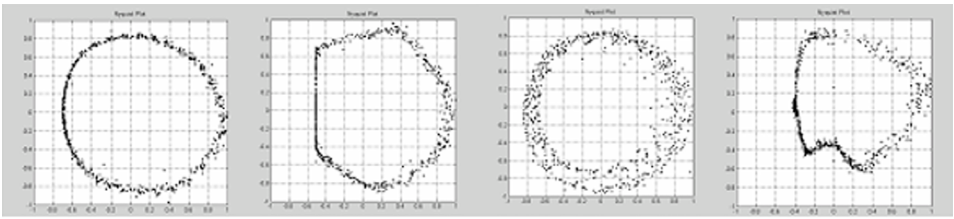
Pattern I indicates a good voice quality with little scatter and harmonic distortion and having an open quotient (OQ) value of approximately 0.75.

Pattern II shows a flattened left side that we have associated with an excessive closed phase and an OQ value of 0.6. These properties are associated with a slightly pressed (or over-pressured) voice quality [2-3, 7-11].

Pattern III shows a slight increase in scatter and breathy quality compared to pattern I with incomplete closure and an OQ value of 0.8.

Finally pattern IV shows distinct local harmonic distortion, which we associate with an increase in non-linearity. This property can be indicative of deviant voice conditions.

The percentage of subjects across gender and age for each pattern is listed in the lower table of Figure 2. The majority (93%) of young subjects analyzed in this study exhibited Patterns I, II and III. Pattern IV was poorly represented in young female and young male groups (8% and 6%, respectively), whereas it was found for 25% of older females.



Pattern I Pattern II Pattern III Pattern IV

Nyquist Pattern / Subject	I	II	III	IV
Young females	**50**%	27%	15%	8%
Young males	24%	**70**%	0	6%
Old females	10%	**45**%	20%	25%

Figure 1. (Top) 50 normal voices across gender and age were analyzed and categorized into 4 distinctive Nyquist patterns. Pattern I: Normal voice - low scatter and harmonic distortion, OQ=0.75; Pattern II: Over-pressured quality, OQ=0.6; Pattern III: Increased scatter and breathy quality, OQ=0.8; Pattern IV: Distinctive harmonic distortion. (Bottom) Table shows gender and age specific voice quality as characterized by Nyquist patterns.

The HSDP-derived GAW also generated perturbation measures for the 50 subjects analyzed above, indicating that the relative jitter and shimmer measures for young subjects are within a range of 0.49% to 4.7% and 1.6% to 6.9% respectively while these measures for the aging group range from 1.4% to 8.3% and 3.2% to 15.7%, respectively.

Our results suggest that: (1) values of jitter and shimmer increased in older subjects with an average value of 4.5% for jitter and 6% for shimmer compared to an average of 2% (jitter) and 4% (shimmer) for younger subjects; (2) variations in the values of jitter and shimmer increased among the older subjects; and (3) variations in the values of jitter and shimmer were similar for young females and young males.

Future studies involving a larger number of subjects across age and gender will allow us to investigate whether pattern IV can be associated with specific age-related voice disorders or whether it is simply characteristic of natural aging. These studies will also lead to a better understanding of the relationship between specific vibratory properties of the VF and the four Nyquist plot-derived categories.

The effect of aging on symmetry of the bilateral VF vibrations

The results of analysis of HSDP recordings from two female subjects (29 and 79 years of age, respectively) with no documented voice complaints are shown in Figure 2.

The VF displacements (left fold displayed in black and right fold in red) were extracted from HSDP recordings of the two subjects. Figure 2 A & C show the displacements of the medial portion of the VF. A quantitative measure of the asymmetry for vibrations of the bilateral folds showed that there was a higher degree of asymmetry (DAS) in the older voice (Figure 2C) compared to the younger one (Figure 2A). Specifically the DAS values in the younger voice (left-right asymmetry) at the anterior, medial, and posterior loci were 0.0381, 0.016, and 0.0793, respectively. On the other hand the corresponding DAS values for the older voice were significantly higher at 0.413, 0.224, and 0.189, respectively.

Interestingly, we show that the same conclusion can be drawn from a qualitative inspection of the overlap between Nyquist plots representing the vibrations on the left fold (black waveform) and right fold (in red) for the young (Figure 2B) and the old (Figure 2D) voices. Future clinical studies on a large number of normal subjects across gender and age will allow us to rigorously test the hypothesis emerging from our limited study, namely that aging causes an increase in the asymmetry of the VF vibration.

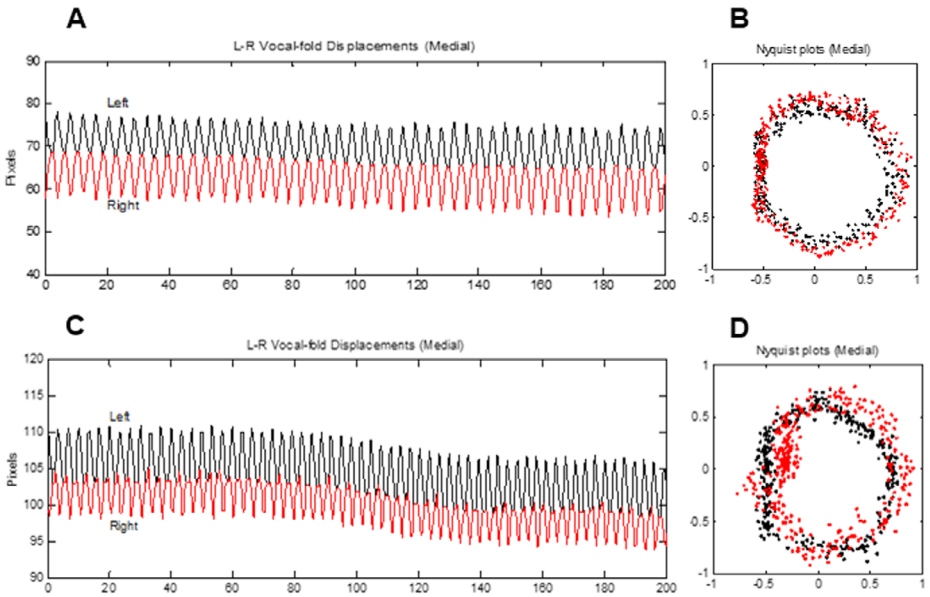


Figure 2. Symmetry property of the vibration of the bilateral VF. (A & C) VF displacements extracted from the HSDP recordings of the young and older subjects, respectively. (B & D) an overlap of the Nyquist plots representing vibrations at the left (black) and right (red) VF for the two subjects, respectively.

Conclusions

We have demonstrated here that analysis of HSDP derived VF vibratory behavior can be easily handled by application of Nyquist plot with co-analysis of acoustic signals to provide a user-friendly interpretation of massive data that may enhance understanding of both normal and specifically abnormal phonation processes.

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