VOICE REGISTERS, VOCAL FOLDS VIBRATION PATTERNS AND THEIR PRESENTATION IN VIDEOKYMOGRAPHY

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Abstract: Videokymography is a high-speed optical method, which provides good presentation of irregular vibration or fast events. Voice register is one of important characteristics of voice quality. Particularly we can distinguish pulse, modal and falsetto register. All registers have characteristic videokymographical and acoustical patterns. Modal voice presents itself in videokymography as regular vibration with large closed quotient whereas falsetto exhibits a small closed quotient. Register break is a transition state between registers, often accompanied by irregularities. On the other side, irregularities are typical for voice disorders. Examples of the register breaks and irregular vibrations registered by videokymography are presented here and are compared to results from other diagnostic methods.

1. Introduction

Voice quality is a multidimensional problem. There are many views and approaches, which divide voice quality to different categories. Categorization and description of voice quality depends an investigation method. In this paper we present vocal register properties as registered by videokymography and irregular vocal fold vibrations in the voice register transition and in voice disorders.

2. Vocal (voice) registers

Voice registers still remain to be a disputed and not unified problem. A loanword nomenclature "register" comes from a church pipe organ register, where register means integration of different organ pipes to create specific tone (acoustical timber).

Literature most often quotes Hollien definition of vocal register: "...a totally laryngeal event; it consists of a series or a range of consecutive voice frequencies which can be produced with nearly identical *phonatory quality*..." Hollien further stated that "...the operational definition of a register must depend on supporting perceptual, acoustic, physiologic, and aerodynamic evidence."[2, 9]

Titze defined the vocal registers as perceptually distinct *regions of vocal quality* that can be maintained over some ranges of pitch and loudness."[10]

Anyway, the vocal register is a perception category, which divides whole voice region in the component registers by the voice quality. Production of voice registers could be described from acoustical or physiological point of view. In particular we can distinguish three main factors influencing the voice register production:

- **configuration of larynx** – phonatory settings (mechanism of oscillation of the vocal folds);
- **vocal tract resonance** (formants setting influence resultant spectrum);
- **interaction of the** subglottal and supraglottal **resonances with the vocal fold oscillations**.[6]

Phonatory settings involve mechanism of using of the laryngeal muscles. The main influencing factors are the vocal fold's length, adduction and tension. The essential condition for vocal register production is participation of the body and/or the cover of vocal folds in vibration.

Vocal tract resonance influences the resulting acoustical spectrum, which affects voice quality perception.

Interaction of the subglottal and supraglottal resonance with the vocal fold oscillations still requires research.

Vocal registers nomenclature is probably the most controversial problem. In history, mainly voice pedagogues named the vocal registers, their description was non-uniform and not objectively documented. Different groups of pedagogues described and divided vocal registers in different way, so that there could be different names for similar registers.

From literature [2,6,7,9,10] we can assume that there are different registers for singing and speech. In speech **pulse** (vocal fry); **chest/modal**; **falsetto** and **whistle** [9] registers are recognized (in ascending scale to pitch); in singing the **chest**; **head** and **falsetto** for males; and chest; middle and head for females. Occasionally there is described the **flageolet** register. [6,9]

Objective characterization of vocal registers could be done only by measurements of acoustical and physiological properties of phonation, but our time used methods are limited of their opportunities.

2.1. Transition between registers

Perception and presentation of different vocal registers are most pronounced when changing the voice quality in vocal register breaks. This change could be **sudden** – abrupt, or **smooth**. [1,6,9]

Smooth change is characteristic for classical educated singers, who use mixing of adjacent registers. The change is difficult to be perceived in this case.

Abrupt change occurs in non-singers, or modern style singers. Well-know examples of register breaks are vocal jumps in young men suffering from voice mutation.

2.1.1. Transition from pulse to modal register

Acoustical sign of this transition is perception of continuity of the neighboring pulses. Fundamental frequency for pulse register is very low and glottal pulses are perceived separately. [1,6,9] There is broad band noise in the spectrogram. Modal register is normal, which is mainly used in spontaneous speech. Videokymography shows doubling of periods for pulse register and normal periodical movement for modal.

2.1.2. Transition from modal to falsetto register

This transition is generally the best known. Perceptually there is a marked change of voice timber. Falsetto, unlike modal register is characterized by thinner, softer voice quality (false voice) like female quality for men. Spectral differentiation of registers is spectral slope: smaller for modal (-12 dB/oct.) and steeper for falsetto (-18 dB/oct.). [4,6,9] In videokymography there occurs insufficiency of glottis in falsetto and normal closed phase (20-40%) in modal. [6,7] Vibration of lower margin of vocal folds differs between the modal and falsetto. In transition we could observe period-doubling – a phenomenon characteristic for nonlinear systems. [1,6] In spectrogram there are visible subharmonic frequencies.

2.1.3. Transition from falsetto to whistle register

This event is not so common and its characterization is difficult. In whistle usually only the front parts of vocal folds vibrate, therefore produce quite high frequencies, and may be described as a *tiny* voice quality. [9]

3. Material and methods

In our paper we presents several cases of vocal register transition between modal and falsetto registers. The examples were selected from database of over 8500 voice examinations using the combination of stroboscopy, videokymography and electroglottography.

3.1. Videokymography

Videokymography is an optical high-speed method for investigation of vibrations of vocal-fold vibrations. Special videokymographical camera is able to work in two different modes: standard (50 interlaced fields per second) and high-speed (8000 line/s). [5,7]

3.2. Electroglottography (EGG)

Electroglottography is technique that monitors the vocal fold contact area in phonation, is an easy and non-invasive way. Two electrodes are placed on the neck of the subject, generating a high-frequency modulated current the admittance of which varies with the vibratory movements of the glottis: it increases as the glottis closes. EGG signal is related to the vocal folds contact area: the larger the contact surface, the larger the measured admittance. [1]

4. Results

In several cases we present videokymographical slides and acoustical patterns of the voice registers transitions.

4.1. Case JJ, male, 22 year old, S31/83

The patient was suffering from prolongation of voice mutation. His voice was characterized as unstable; with often occurring voice breaks from modal to falsetto register and back.

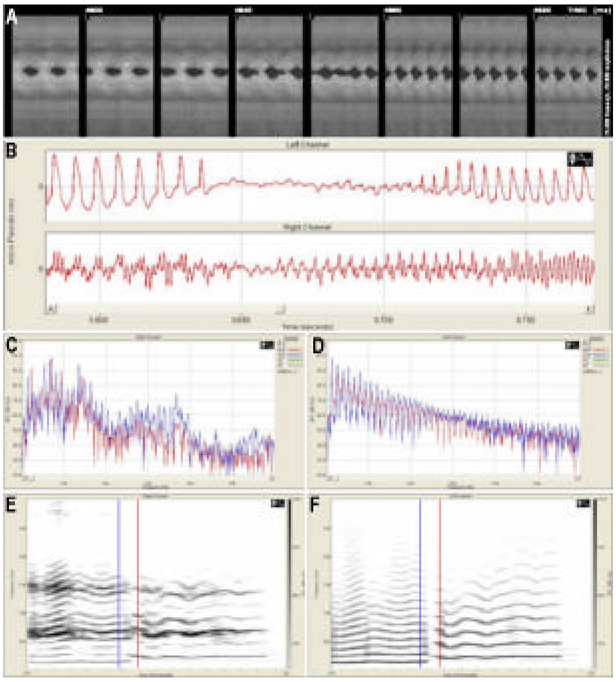

Figure 1. Register break from modal to falsetto register. **A:** Chain of kymographical slides during the register change. Between the modal and falsetto there occurs a segment with period doubling.. **B:** Electroglottographic (top) and acoustical (bottom) signal of the register break between the blue and red lines in (E,F). **C,D:** Acoustical (C) and EGG (D) spectra of modal F_{0m} ~ 136 Hz (blue) and falsetto F_{0f} ~ 236 Hz (red) register. **E,F:** Spectrograms of acoustical (E) an EGG (F) signals. Blue line depicts the start of the kymographical chain (A) in modal register and the red line ends in falsetto.

4.2. Case WA, female, 77 year old, S62/69

The patient was suffering from aging voice. Her voice was characterized as weak and unstable; with often occurring voice breaks from falsetto to modal register.

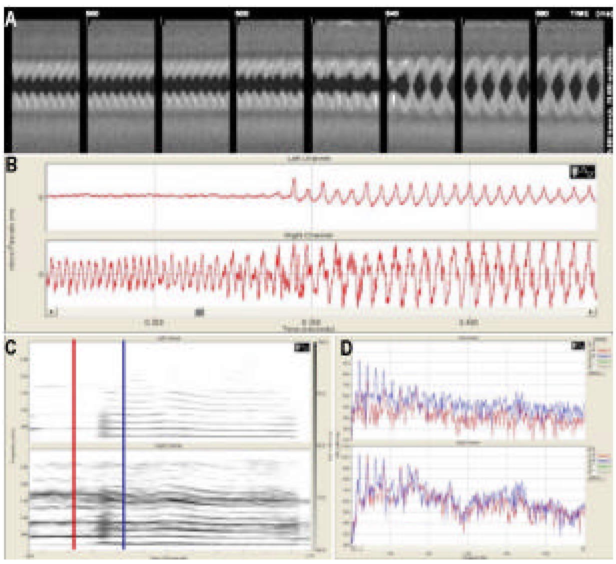

Figure 2. Transition from the falsetto to modal vibration. **A:** Chain of kymographical slides during the register change. Between the regular vibrations there occurs a segment of irregular pattern with period doubling. **B:** Electroglottographic (top) and acoustical (bottom) signal of the transition between the blue and red lines in (C). **C:** Spectrograms of EGG (top) and acoustical (bottom) signals. The blue line depicts the start of kymographical chain (A) in falsetto and the red line ends in modal. **D:** EGG (top) and acoustical (bottom) spectra of modal F_{0m} ~ 204 Hz (blue) and falsetto F_{0f} ~ 416 Hz (red) register.

4.3. Case PK, female, 27 year old, S73/37

The patient was suffering from paresis m. transversi after viral infection. Her voice was characterized as weak. Instabilities occurred when she wanted to increase the loudness of voice.

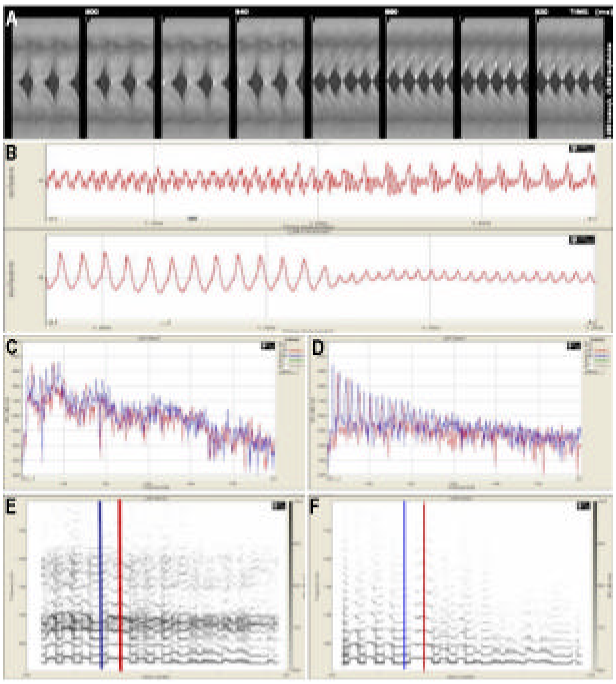

Figure 3. Abrupt change from falsetto to modal vibration. **A:** Chain of kymographical slides of register change. **B:** Acoustical (top) and EGG (bottom) signal of register break between the blue and red lines in (E,F). **C,D:** Acoustical (C) and EGG (D) spectra of modal F_{0m} ~ 147 Hz (blue) and falsetto F_{0f} ~ 250 Hz (red) register. **E,F:** Spectrograms of acoustical (E) an EGG (F) signals show voice instability - several successive breaks. The blue line depicts the start of the kymographical chain (A) in modal and the red line ends in falsetto.

4.4. Case MM, female, 27 year old, S80/1

The patient was suffering from bilateral vocal fold cysts. Her voice was unstable, weak and rough. Often there occurred voice breaks from modal to falsetto register and back.

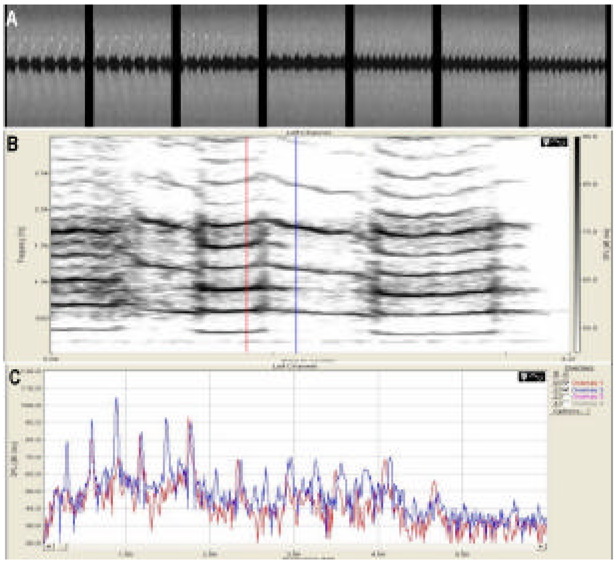

Figure 4. Transition from modal to falsetto vibration. **A:** Chain of kymographical slides during the register change. **B:** Spectrograms of acoustical signal shows voice instability - several successive breaks. The blue line depicts the start of kymographical chain (A) in modal and the red line ends in falsetto. **C:** Spectrum of acoustic signal, modal F_{0m} ~ 225 Hz (blue) and falsetto F_{0f} ~ 545 Hz (red) register.

5. Discussion

Accurate, definite and general characterization of vocal registers is very difficult. An important issue is the methodology of investigation of the registers. Various methods have been used, but many of them are invasive and their use can introduce measurement errors by stimulating unnatural vocal behavior. Furthermore the correspondence between acoustical and optical methods is not straightforward. Here we presented specific examples of register breaks. We found that breaks occur not only in mutation voices, but also in other voice disorders. A question arises whether the vibration patterns of the vocal folds always correspond to the standard voice registers.

6. Conclusion

Presented cases showed distinct changes in the vibration behavior of the vocal folds. These changes were perceived as vocal register breaks with abrupt jumps of pitch and abrupt changes of voice quality. In several cases there could be observed transitions with sudden changes in vibration, in other cases there were progressive changes with instability segments and period doubling in videokymographical slides.

Acknowledgements

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References

[1] Henrich N., Roubeau B., Castellengo M. (2003): On the use of electroglottography for characterisation of the laryngeal mechanisms, In proc. Stockholm Music Acoustics Conference (SMAC 03), Stockholm, Sweden, Aug. 2003.

[2] Hollien, H. (1974): On vocal registers, *Journal of Phonetics*, 2,125-143.

[3] Švec, J. and Pešák, J. (1994): Vocal Breaks from the Modal to the Falsetto Register, *Folia Phoniatr.* Logop. 46, 97-103.

[4] Švec, J.G., Schutte, H.K., and Miller, D.G., (1996): A Subharmonic Vibratory Pattern in Normal Vocal Folds, *Journal of Speech and Hearing Research*, 39, 135-143.

[5] Švec JG, Schutte HK (1996): Videokymography: High-Speed Line Scanning of Vocal Fold Vibration, *Journal of Voice*, 10(2): 201-205.

[6] Švec J. (1996): Studium mechanicko-akustických vlastností zdroje lidského hlasu. [Studies of the Mechanical-Acoustical Properties of the Human Voice Source]. (Doctoral Dissertation, in Czech). Faculty of Natural Sciences, Palacký University, Olomouc, the Czech Republic.

[7] Švec, J.G., Schutte, H.K., and Miller, D.G. (1999): On pitch jumps between chest and falsetto registers in voice: Data from living and excised human larynxes, *Journal of the Acoustical Society of America*, 106 (3), 1523-1531.

[8] Horácek J., Švec J.G., Veselý J., Vilkman E., Klepácek I., Vetešník A. (2001): Measurement of the vocal-fold vibration behaviour in excised human larynges, In: Proceedings of the 2nd International Workshop on Models and Analysis of Vocal Emissions for Biomedical Applications. Firenze, Italy, September 13 – 15.

[9] Thurman L., Welch G., Theimer A., Klitzke C. (2004): Addresing vocal register discrepancies: an alemative, science-based theory of register phenomena. Second International Conference The Physiology and Acoustics of Singing National Center for Voice and Speech 6 – 9 October 2004 Denver, Colorado, USA.

[10] Titze, I.R. (1994): Principles of Voice Production. Prentice Hall, Englewood Cliffs, NJ.