Chapter 20
Mucosal wave characteristics in simulated vocal overpressure. A preliminary study using LVS & HSDP with analysis by kymography, P-FFT & Nyquist plots

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Abstract
In this preliminary HSDP report we focus on in vivo observations of not only of the glottic region, but on supraglottic laryngeal posturing during simulated production of vocal overpressure (VoP) as well. Resultant data were analyzed with spatio-temporal algorithms capable of describing vibration patterns of vocal folds (VF), multi-line kymograms, spectral P-FFT analysis, and Nyquist spatio-temporal plots. Results reveal that supraglottic contraction assists in prolonged closed phase of the vibratory cycle in VoP and that prolonged closed phase is long in VoP, but not as long as in vocal fry. In our opinion, these findings lead to a better differential diagnosis, and hence to a more efficacious treatment.

Keywords: HSDP, LVS, female voice, VoP, dysphonia, mucosal wave, glottic cycle, GAW, PFFT, Nyquist plots

Introduction
VoP, also known as pressed phonation, presents with strained-strangled voice quality often with vocal arrests when present in pathological dysphonia of dystonic nature and with fry type strain when present in non-dystonic conditions [1]. However, information on how overpressure is produced physiologically is scarce. This may lead to problems with clinical diagnosis and treatment of VoP. Hence improvement in our understanding of what constitutes VoP is welcomed.

HSDP provides an opportunity to enhance our knowledge of VoP by providing detailed data on glottic posturing during phonation and by providing detailed real-time information about laryngeal biomechanics that include observations about: mucosal wave, wave motion directionality, glottic area wave form, asymmetry of vibrations within and across VF, and contact area of the glottis including false VF contribution.

VoP can be present in dystonic conditions, in vocal strain, and in ventricular dysphonia [1-3]. Acoustic, EMG, and LVS studies of clinical overpressure demonstrate over-contraction of intrinsic laryngeal musculature including compression of supraglottic structures during VoP [4] and elimination of VoP to normal voice once muscle spasms are eliminated [5-6].
To gain more information of how VoP is produced, we used HSDP to provide visual images of the glottal area in this condition. We feel that these data will be instrumental in modifying phonatory pathological and normative models of VoP.

**Materials and methods**

All data were recorded using color HSV system (KayPENTAX Model 9710, NJ, USA). Standard phonoscopic signal acquisition without topical anesthesia was used [7]. The rate of video frames was set to 2000 with maximum available image resolution of 512 x 512 pixels. Acquired signals were processed by KIPS (KayPENTAX) when appropriate and using custom programs such as Vocalizer® elsewhere [8-9].

HSDP were compared to LVS images obtained from the same subject on the same date with the use of standard LVS equipment (Kay Elemetrics RLS 9100, NJ, USA).

**Results**

All modes of phonation are determined by the action of the intrinsic and the extrinsic LM that determine specific pitch ranges and the transitions to these ranges from the modal range [8]. These muscular adjustments expressed by VF positioning is shown in detail in HSDP imaging. Therefore the kinematics obtained via HSDP are superior to those obtained from LVS.

Figure 1 shows a birds-eye view of the glottis during production of VoP captured by LVS and HSDP. Although both LVS and HSDP show severe supraglottic constriction, details of mucosal wave (MW) can be discerned only from HSDP.

![Figure 1. Birds-eye view of the glottis from LVS and HSDI. Both show severe supraglottic constriction during VoP; MW can only be discerned from HSDP.](image)

Figure 2 show KIPS kymograph of VoP. Note prolonged closed phase of the glottic cycle and very symmetrical glottic wave pattern between the R and the L TVC.

Figure 3 shows Vocalizer® [10-11] analysis of GAW of VoP derived from HSDP demonstrating pulse like bursts alongside the entire glottis length.

P-FFT of VoP is demonstrated in Figure 4. Note that regularity of MW and rich harmonic structure of the generated fundamental frequency (F0). It also demonstrates little difference for corresponding points from left vs. right VF locations.

To provide more information on the acoustics of VoP versus normal phonation we also generated Nyquist plots [10-11] from voice signals alone. These plots are shown respectively in Figure 5.
**Figure 2.** KIPS kymograph of VoP. Note prolonged closed phase of the glottic cycle and very symmetrical glottic wave pattern between the right and left true VF.

**Figure 3.** Vocalizer® analysis of HSDP (top) to generate GAW of VoP showing pulse like burst alongside the entire glottis length (bottom).
Summary and conclusions

LVS and HSDP are equally informative about supraglottic topography with LVS failing to expose fine movements of these structures. Hence, HSDP is superior in demonstrating details of the MW and VF kinematics. Based on these findings we conclude that MW is suppressed in VoP in the time domain. Although closed portion of the glottal cycle in vocal fry is known to be the longest among the many voice qualities studied by HSDP, it is also prolonged in VoP.

Although these two modes show supraglottic contraction, this medial motion of the supraglottic structures has different effects in each of the two modes. Specifically, it was demonstrated via HSDP that this medial compression allows for the false VF to “oscillate” in VoP mode, but not in fry phonation despite their midline approximation. Acoustic Nyquist plots revealed fine structures of F0 in each of these modes while P-FFT showed left versus right differences.
References
