ON PRESSURE-FREQUENCY RELATIONS IN THE EXCISED LARYNX

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Subglottal pressure and the fundamental frequency of the voice are two primary control variables of phonation, the former highly related to the loudness of the sound produced, and the latter to the perceived pitch of the voice. These two variables are not independent. Subglottal pressure has been shown to have a major influence on the fundamental frequency (Fo) and intensity of phonation (e.g., Koyama, Harvey & Ogura, Laryngoscope 1971, 81, 45-65; Titze, J. Acoust. Soc. Am. 1989, 85, 901-906). It has been reported that the relation between transglottal pressure and fundamental frequency is a linear positive relation. It is also reported by Titze (1989) that Fo and amplitude of oscillations are not independent of each other. Another oscillation parameter that is obtained from the pressure-Fo relation is the rate of change in Fo with pressure, or dF/dp. This parameter is reported to have almost a "V" shape behavior as a function of frequency. That is, it has a minimum at some frequency and increases as frequency increases or decreases from that value (Kataoka & Kitajima, Ann. Otol. Rhinol. Laryngol. 2001, 110, 556-561).

In these prior studies, pressure and flow were varied in a stepwise fashion and the derivative of the pressure-Fo relation was calculated from the stepwise differences.

The purpose of this study was to improve upon these studies and provide more continuous pressure-Fo data, and to investigate the range of the parameter dF/dp during transitions in phonation mode.

Excised canine larynges were obtained following cardiovascular research experiments at the University of Iowa Hospitals and Clinics. They were quick-frozen using liquid nitrogen for storage and slowly thawed in a refrigerator prior to use. Each larynx was mounted on 3/4-inch PVC tubing mimicking the trachea so that the glottis was easily viewed by a camera and accessible by the equipment. Adduction was created either by the placement of metal shims of various thickness (0.1 - 1.0 mm) between the arytenoid cartilages or by a pair of sutures pulling the muscular process of each arytenoid cartilage, to simulate the lateral cricoarytenoid muscle action as in arytenoid adduction. Each excised larynx was subjected to an increasing pressure-flow sweep for about 20 seconds (from lowest to highest flow rate) with adduction and elongation as the major control parameters. The pressure, flow, and Fo measures were obtained for these pressure sweeps.

Analog data including the EGG signal, subglottal pressure, mean flow rate, and the microphone signal were recorded on a digital audio tape recorder (DAT) during each experiment. Pressure-flow and pressure-Fo relationships were obtained from these recordings. The EGG signal was used to examine the spectrogram of each data section. After identifying the fundamental frequency range, the signal was digitally low-pass filtered just above maximum Fo and used to calculate an average period of the segment (using approximately 10 cycles; zero crossing technique). The mean pressure for each segment was also calculated and used in the pressure-Fo data.

Preliminary data (analysis of a portion of the recordings corpus) indicate an almost linear relation between mean pressure and flow that is moved toward lower flow rates and higher pressures with increasing adduction (suture force value). This result has been reported before (by us) for excised larynx data, but using a pressure-flow sweep technique here enables us to obtain such data in a 20-second run and calculate the glottal flow resistance easily as suggest by Figure 1. The pressure-Fo relation is nonlinear as shown in the Figure 2. This nonlinearity contradicts previous reports of linearity. It indicates stronger effects of pressure on frequency at higher pressures. This effect or the change of frequency with pressure is shown in

Figure 3. This rate of change of frequency with pressure is highly sensitive to the frequency and showed a decreasing trend at lower frequency from 6 to a minimum of about 1.7 at around 245 Hz and an increasing trend thereafter. This is in agreement with findings of Kataoka & Kitajima (2001).

The nonlinearity of the pressure-frequency data suggest that the pressure control of fundamental frequency varies in its sensitivity to Fo change, depending upon the level of pressure, and less so on the level of adduction. Relative to the control of Fo in running speech, the wide range of values for dF/dp suggests a dynamic relationship between the passive pitch change from transglottal pressure change, and the necessity to alter Fo using the CT and TA muscles.

Data will be reported for a wide range of vocal fold length and adduction, where the given tension of the vocal folds relatively to length is expected to have a strong effect on the value of dF/dp. Preliminary data on the effects of elongation suggest large ranges of oscillation frequency and possibility of changes in oscillation mode. The pressure frequency relationship might have a sharp change when the larynx changes its oscillation mode as shown in Figure 4.

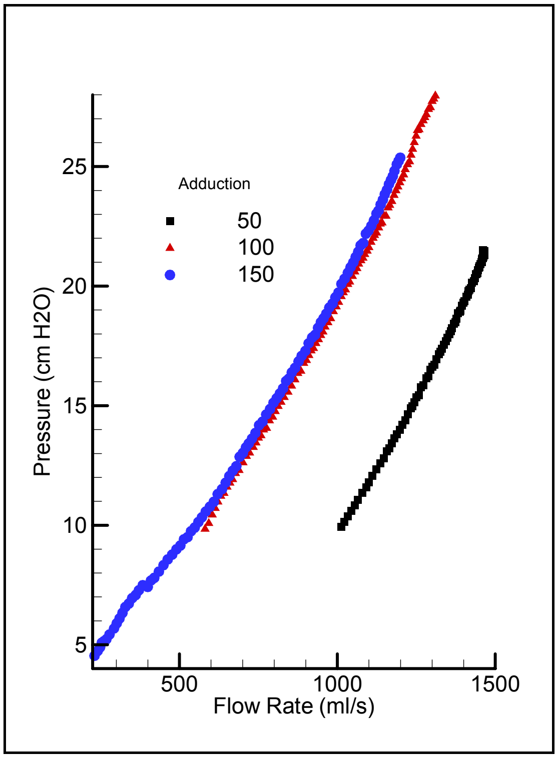

Figure 1. Pressure- flow relationship

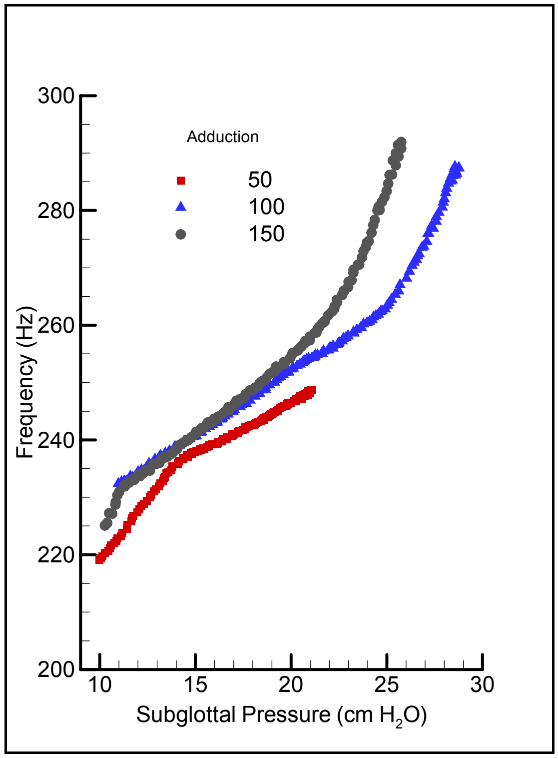

Figure 2. Pressure- pitch relationship

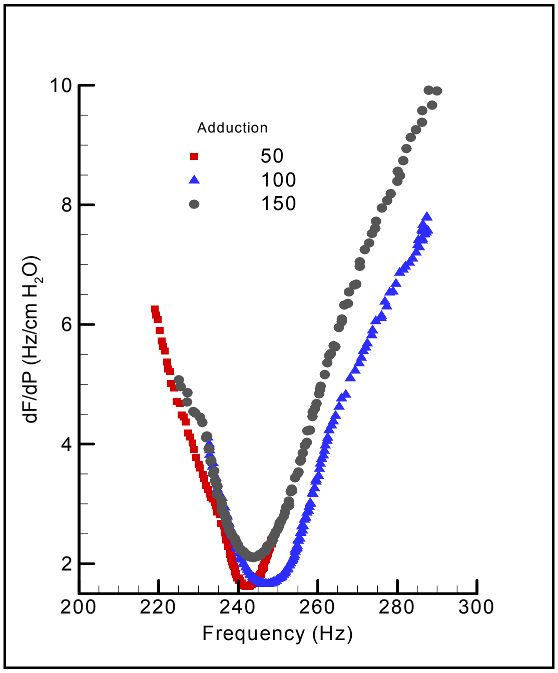

Figure 3. Rate of pitch changes

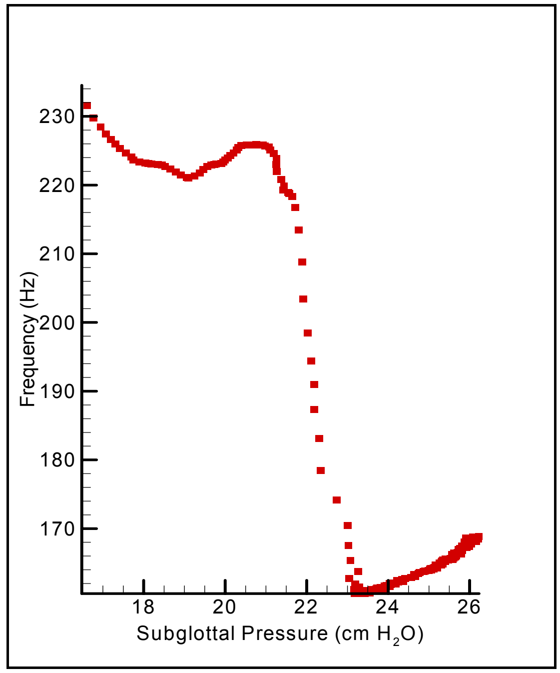

Figure 4. Pressure-pitch relations during phonation mode change