

# Naturally Occurring Sulcus Formations in Canine Larynxes

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## Abstract

The effects of scarring are well demonstrated in sulcus vocalis, a voice pathology found in a small percentage of the clinical population. Vocal fold scarring causes a significant dysphonia, which is difficult to treat successfully by either behavioral management or surgery. While the general consequences of sulcus vocalis are known, the effects of differences in the extent of sulcus vocalis on the biomechanics of voice production are less understood. Unfortunately it is not possible to make systematic studies in a clinical population because of the large heterogeneity in location and depth of the fibrosis between subjects.

Edema and sulci are a naturally occurring phenomena in canines with kennel cough, which provides a means to study the vibratory characteristics of sulci in a controlled laboratory setting. Since the predominance of excised larynx data exists from the canine model, naturally occurring general vocal fold edema and various sulcus formations in the canine model is ideal for comparisons to existing literature. Specific variables of interest include: glottal resistance, dominant modal patterns, and vocal economy – an acoustic output/cost ratio. Thus, the purpose of this study is to examine the vibratory characteristics of naturally occurring sulcus vocalis in 5 excised canine larynxes. Histology was completed to confirm sulcus formations.

Subglottal pressure was varied in 0.2 kPa steps from phonation threshold up to approximately 2.6 kPa. At each step, DC subglottal pressure and airflow were documented from a manometer and rotometer, respectively. Acoustic output intensity was collected from a sound-level meter, which was oriented 10 cm from the glottal air jet at a 45° azimuth (rotation angle) and 45° elevation angle. A superior view was captured during each steady state subglottal pressure with a Kodak EktaPro 4540 high-speed digital imaging system. Each captured segment was imaged for 2/3 of a second at a sampling frequency of 4500 frames per second, with a total image resolution of 256 X 256 pixels. The images were black and white with 256 levels of grayscale. Each captured segment was digitally transferred to a personal computer for later analysis.

Vocal economy was measured as output (in dB SPL re: 20 micro-pascals) divided by cost (in dB re: 0.1 kPa) that yielded a dimensionless measure (dB/dB). Mean values for vocal economy ranged between 2.67 and 3.46. Glottal resistances were found to generally have linear regression. The mean values ranged between 0.002 and 0.01 kPa/(ml/sec). Also, glottal resistance increases correlated with vocal economy decreases because of the expected decrease in amplitude of vibration from scarring that created an increase in glottal resistance, which in turn yielded decreased acoustic output, and hence a decreased output/cost ratio (vocal economy). The dominant modal patterns in the

disordered larynxes deviated from the 11 mode with increases in stiffness changes due to likely asymmetric changes in tissue degrees of freedom for vibration. An increased asymmetry in modal patterns did not necessarily correlate with a poor output/cost ratio.

Overall, there appears to be differences in excised vibration of canine vocal cords that have naturally occurring sulcus formations. These data suggest that as the stiffness changes associated with either edema or scar formations are likely asymmetric, creating asymmetry and aperiodicity during phonation. However, asymmetry and aperiodicity did not always yield the lowest vocal economy.

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