Flow-induced Vibrations of the Uvula and Its Implication on Snoring

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Abstract

Background: Previous studies attempting to define the relationship between snoring and the anatomy of human upper airway systems have predominately implemented a rigid airway model due to its geometric complexity as well as limited availability of computational tools on fluid-solid two-way coupling interactions [1]. However, since human snoring is fundamentally a flow-induced phenomenon, the flow fluctuations due to this nature need to be accurately modeled to better understand the snoring mechanism. In addition, small anatomical details can significantly impact sound energy generation and propagation, necessitating a high degree of accuracy when modeling the airway geometry.

Objectives: To simulate the flow-induced vibrations of a uvula (soft palate) with varying flexibilities and its influences on the acoustic characteristics of snoring.

Methods: A physiologically realistic nose-throat airway was developed based on medical images. Elastic properties of the airway were specified differently for hard and soft tissues [2, 3]. First, an idealized two-dimensional nasal geometry was studied to identify the fundamental snoring frequencies from static and vibrating uvulas. Second, the three-dimensional physiologically accurate nose-throat model was implemented to refine the correlations between snoring and the uvula movements. The fluid-structure two-way coupling feature in COMSOL Multiphysics® was used in this study.

Results: Individual airway anatomies such as the uvula, pharynx, and larynx exerted a significant impact on breathing resistance and energy distribution of the acoustic sound. An abrupt pressure drop resulting from the uvula-related airway obstruction was observed. The uvula vibrations considerably altered flow dynamics compared to a static uvula, and changed the fundamental frequencies and acoustic power levels. Each anatomy source was observed to generate a unique spectrum, which could be distinguished from others by its signature peak frequencies and energy distribution. Moreover, severe pharyngeal airway narrowing led to an upward shift of sound energy in the high frequency range.

Conclusion: Results of this study indicated that including the vibrations of the airway structures is crucial to better understand snoring generation mechanisms and breathing-related disorders. Specifically, high-frequency acoustic signals may disclose additional clues to the mechanism of

apneic snoring and should be included in future acoustic studies.

Reference

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