An Upper Airway Model for Studying the Acoustic Properties of Breathing Sounds

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***Abstract*—The acoustics of the upper airway may provide useful insights to medical conditions such as snoring and obstructive sleep apnea. This study is intended to create an artificial airway model that has acoustic properties similar to those of the humans. A silicone rubber head model with anatomically correct nasopharynx, oropharynx, and trachea was built. A respiration pump was used to drive air in and out of the airway, simulating inhalation and exhalation of the human respiratory cycle. Measurements were taken by use of an electronic stethoscope positioned near the area of the suprasternal notch. Frequency spectra showed an increased in high frequency components when the trachea was blocked by about 90%. The silicone head model provides a controlled environment for studying the effects of blockages at various part of the upper airway on the acoustic properties of the breathing sounds.**

Keywords— silicone head model; upper airway; breathing sound; frequency spectrum;

I. INTRODUCTION

Sleep apnea is an under diagnosed disease that has gained much attention in recent years. The collapsed airway causes momentary pauses in breathing during sleep, which often interrupts the deep sleep stage. and this causes the brain to send a signal to wake up due to the lack of air intake in the lungs. Abruptly waking up from a deep sleep may increase the risk of heart attack, stroke, and other heart related issues [1]. To aid the diagnostics of sleep apnea, our laboratory has conducted research on the acoustic properties of the breathing sounds in relation to obstructions in the upper airway.

The current project looks to the characterization of frequency spectrum of a healthy trachea versus that of one which has been obstructed. The project contains two parts. First, a head model that contains a hollow airway needs to be constructed with a single pour of silicone rubber. The silicone model must not includes interfaces that could block the transmission of sounds. Second, the frequency spectra of the airflow sounds created by connecting a respiration pump to the head model are studied. Specifically, the effects of an airway blockage on the frequency spectrum are characterized.

II. METHODOLOGY

A. Overall Instrumentation

As shown in Fig. 1, the breathing is generated by a respiration pump (Harvard Apparatus model 607), which

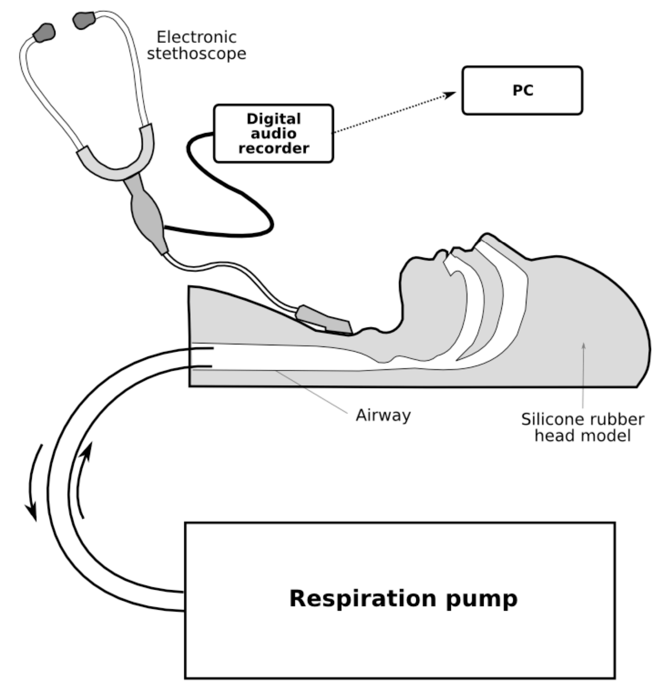

Fig. 1. Silicone rubber head model with attached respiration pump to simulate breathing through the upper airway.

pumps air in and out of the silicone head model. The pump allows for adjustability in the rate of breathing, which is typically set at 18-20 respirations per minute. An minute. An electronic stethoscope (Jabes, GSTechnology, Seoul, Korea) is placed over the trachea near the suprasternal notch. A digital audio recorder (H4N, Zoom Corp., Tokyo, Japan) is attached to the stethoscope and records the airflow sounds. The data are saved as a wav file and uploaded to a personal computer. A MATLAB program performs the fast Fourier transform (FFT) and displays the frequency spectrum.

B. Airway

The techniques for constructing the head model was based on a previous project [2]. To create the airway mold, two blocks of wood were carved and placed together to perfectly match the tracheal dimensions of an adult human. This mold was filled with agar, an algae based substance, with a hardening state stronger than most other types of gelatin. The agar airway model was then placed in a plaster mold of a human head mannequin, anchored down, and filled with the silicone rubber. After the silicone hardened, the agar was removed from the airway with boiling water. The respiration pump is connected to the airway with pneumatic tubings.

C. Silicone Model

To construct the silicone head model, a silicone mix with 10:1 ratio of the hardener was used. This mixture was first poured in a vacuum container allowing for the removal of air bubbles. The silicone was then poured around the agar, which represented out trachea, and was left to harden. Once the silicon set, the agar was removed by pouring boiling water through the mouth and nose and down the center trachea. Figure 1 shows the final head model with the upper airway void.

III. Results

A. Unobstructed Airway

A number of measurements were taken throughout the testing process. The first round of results looked at mimicking the breathing process of a healthy individual with the silicone model. Measurements were taken using a speed of 18-20 beats per minute on the respiratory machine. As shown in Fig. 2, the frequency spectrum is, to some extent, similar to that of the typical frequency spectrum of the human breathing sound, with a low frequency peak around 100 Hz and high frequency components between 300 Hz and 700 Hz.

B. Obstructed Airway

Next, the main trachea was obstructed by inserting clay into it so that approximately 90% of the opening was blocked. The results in Fig. 3 shows a significant increase in the higher frequency range around 600 Hz.

IV. Discussion

This project has successfully produced a silicone head model containing an anatomically correct upper airway. The preliminary acoustic measurements have shown that the model can product airflow sounds similar to those of human breathing. Furthermore, the frequency spectrum is sensitive to airway obstructions, suggesting its potential for studying the acoustic properties of breathing sounds related to obstructive sleep apnea.

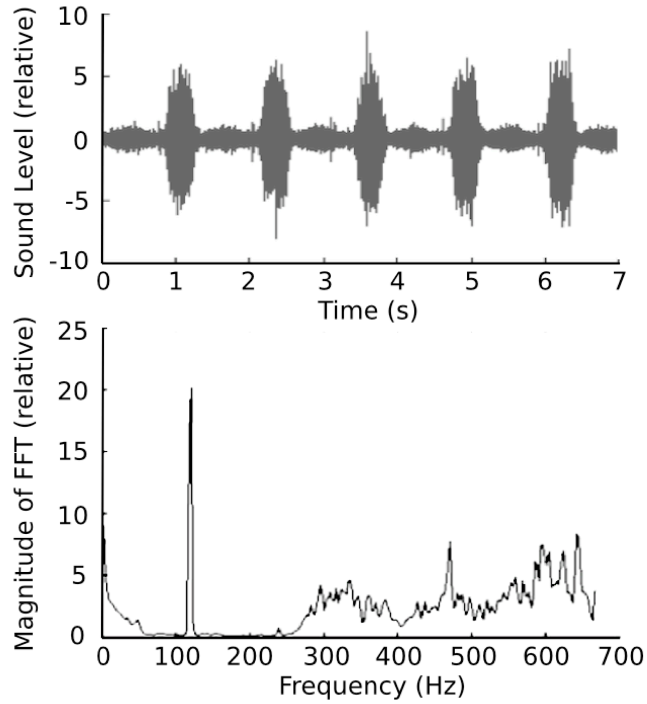

Fig. 2. The airflow sound (top) and the frequency spectrum from an experiment with unobstructed airway

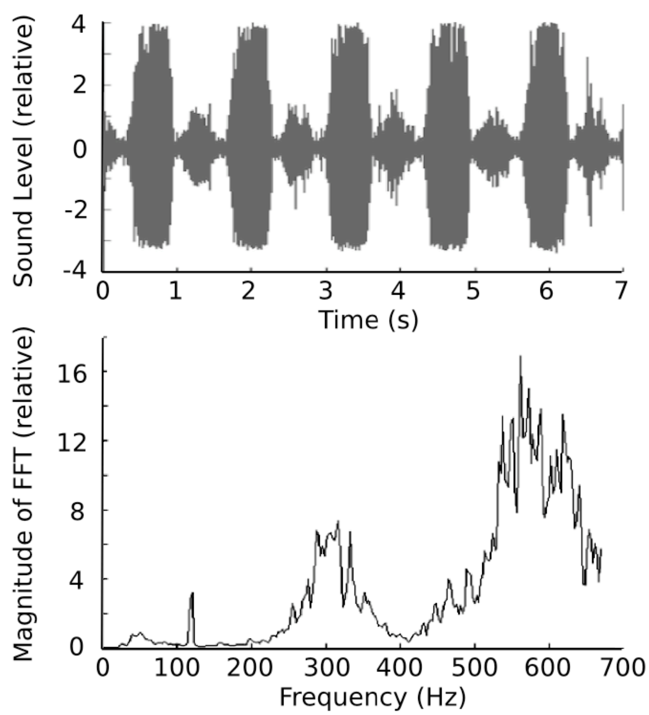

Fig. 3. The airflow sound (top) and the frequency spectrum from an experiment with 90% obstructed airway.

References

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