Mouth Flow Estimation During Cough Sound Measurements

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Introduction & Relevance

Physicians have used the presence and characteristics of cough as a diagnostic tool for many years. Researchers have shown that cough sound analysis can assist in the diagnosis of respiratory disease [1]. Important considerations such as cough intensity and duration may affect the sounds produced by the lungs. To reliably classify cough sounds, these considerations must be addressed. Measurement of cough air flow simultaneously with sound has several advantages. Indices can be derived which estimate the forcefulness of a cough. This information is useful in determining the repeatability of cough sound measurements. Additionally, flow indices could augment existing diagnostic algorithms to improve their ability to distinguish subjects with different types of pulmonary disease. Our challenge was to record the cough air flow accurately without affecting the fidelity of the sound measurement made at the mouth. A system was designed for this task. Hardware was developed to record sound with minimal interference. Reconstruction software was written to estimate flow at the mouth, based on a flow measurement recorded where it would not alter the sound.

Materials & Methods

A system was constructed to measure the sound pressure waves and air flow propagated through the mouth during cough. A cylindrical mouthpiece was attached to a 1" diameter metal tube. A 1/4" microphone (Bruel & Kjaer #4136) was mounted at a 90° angle with its diaphragm tangent to the metal tube. A 1" diameter (1/2" wall), 10' long gum rubber tube was connected to the metal tube opposite the mouthpiece. An HP #21072B pneumotach (P_{system}) was attached to the distal end of the flexible tube. An exponential horn was coupled to the end of the pneumotach. The pneumotach recorded cough flow (F_{system}), the microphone recorded cough sounds while the tubes and horn were used to increase sound fidelity.

A software "virtual instrument" was designed using Labview to provide a user interface and to record experimental data. Custom software was developed in Matlab to analyze cough sound and flow data. The system is similar in nature to that described in an earlier work [2], with the addition of the pneumotach and flow measurement capability.

Due to the large distance (10') between the mouthpiece and the pneumotach, it was assumed the system would filter the flow signal. To determine the filter characteristics, another pneumotach (P_{test}) was added at the input of the system for testing purposes. Flow measured at this point (F_{test})was considered "true" flow. By exciting the system with a flow signal rich with the frequencies of interest, a flow-flow system transfer function can be calculated. Using F_{test} as input and F_{system} as output, a second order digital filter representation (or ARMA model) was calculated using a batch least squares technique. The inverse of this filter (H_{inv}) compensates for the tubing and gives the flow through the tube at the microphone. This technique is similar to that used by Reynolds et al. [3] to accurately reconstruct cough sounds.

A volunteer coughed into the system. H_{inv} was then applied to F_{system} for the cough signal to obtain the estimated mouth flow signal (F_{fit}). The mean squared error (MSE) and % peak flow error (%PFE) were calculated for F_{system} and F_{fit} to quantify the improvement the flow reconstruction technique provided.

Results & Discussion

Compared Signals	MSE (L^2/S^2)	% PFE
F_{test} / F_{system}	0.809	23.3
F_{test} / F_{fit}	0.032	1.68

Table 1. Results of flow reconstruction.

The reconstructed signal improved the MSE by a factor of 25.3 and the %PFE by a factor of 13.9.

Conclusions

The reconstruction technique significantly improved the accuracy of the flow measurement. This allows placement of the system pneumotach further downstream where sound reflections from the capillaries of the pneumotach will have minimal effect on the cough sound recorded at the mouth.

References

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