A Cough Sound-Based Machine Learning Model for Diagnosis of Tracheobronchomalacia

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I. Purpose

Bronchoscopy and dynamic airway computed tomography (DACT) are currently used to diagnose tracheobronchomalacia (TBM). However, these techniques are not available in settings with limited expertise or resources. We sought to determine whether a machine learning classifier applied to cough sound recordings could accurately distinguish TBM patients from healthy controls.

II. Methods

Using an iPhone, we collected a total of 929 cough sounds from 24 adults with diagnosed severe diffuse TBM as well as 18 control subjects. Severe diffuse TBM was defined as complete or near complete collapse (<90% of anteroposterior wall diameter) of the trachea and/or bilateral main bronchi, as demonstrated by dynamic bronchoscopy and/or computed tomography scanning. Cough sounds were manually segmented from the audio recordings. Mel spectrograms were computed from the cough recordings and inputted to YAMNet, a pretrained audio classification model. The model was fine-tuned using a leave-one-subject-out cross-validation approach. Performance metrics were pooled across all folds and evaluated both at the cough and patient level, where patient-level labels were derived from the predicted probability of TBM cough averaged across all coughs for the patient.

III. Results

Representative Mel spectrograms of cough sounds for TBM and normal patients demonstrate differences in frequency distributions of signal energy between TBM and normal cough sounds. The fine-tuned YAMNet model classified cough sounds with a pooled sensitivity and specificity of 0.922 and 0.921 respectively. When cough labels were aggregated at the patient level, the sensitivity and specificity of the classification was 0.958 and 0.944 respectively. The area under the receiver operator curve (AUROC) for cough sound classification was 0.971.

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IV. Conclusion

TBM coughs are distinguishable from normal coughs with high accuracy when analyzed by a machine learning model with limited fine-tuning. Our results highlight the potential of cough sound analysis for improving access and expediency of TBM diagnosis. Further studies should explore larger datasets including patients with TBM and other pulmonary diseases.

TABLE I
Performance Metrics for YAMNet Cough Sound Classifier

	Sensitivity	Specificity	Accuracy
Cough-level classification	0.922	0.921	0.921
Patient-level classification	0.958	0.944	0.952

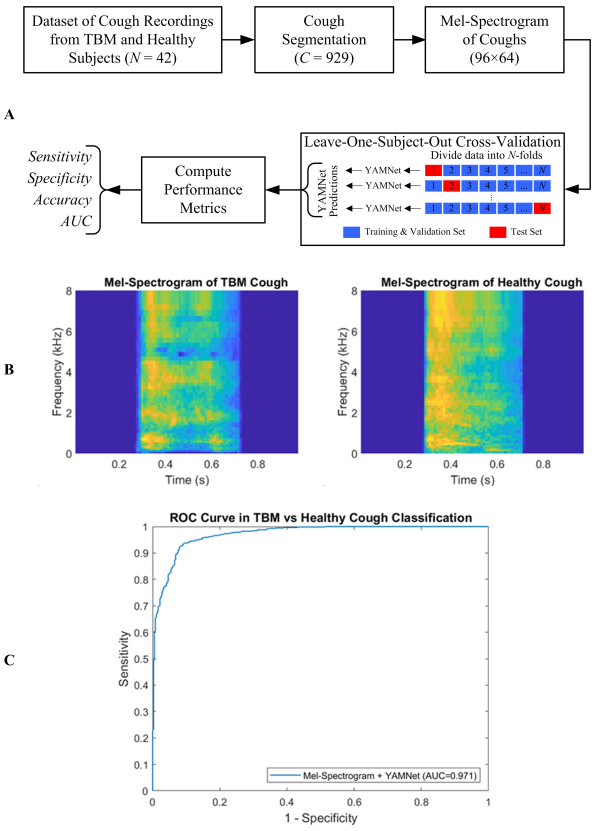

Fig. 1. (A) Workflow for cough sound pre-processing, model development and performance measurement. (B) Spectrograms of representative tracheobronchomalacia (TBM) and normal coughs. (C) Receiver operator curve (ROC) for cough classification model.