

Cough Sound Analysis for Classifying Asthma and Pneumonia in Paediatric Population Based on HMM

¹Dr.F.Emerson Soloman , A karthik ²

¹Assistant Professor ²UG Students,
Department of Biomedical Engineering
BIHER, BIST, Bharath University
Chennai- 6000073.

emersonsoloman.bme@bharathuniv.ac.in

ABSTRACT:

Separating paediatric asthma from paediatric pneumonia is one of the major issues in remote areas. These diseases have overlapping symptoms, but require drastically different treatments. Existing guidelines for pneumonia classification in resource poor regions from The World Health Organization call for the use of bronchodilator test to separate asthma from pneumonia. However, bronchodilator is an expensive test to conduct and not easily available in remote areas. In this study, we propose an innovative and novel technique using cough sound analysis to separate pneumonia cases from asthma. In the work of this paper we analyzed cough sound data from 20 subjects (10 pneumonia and 10 asthma patients). Using mathematical features of cough sounds, an HMM classifier was trained to identify pneumonic cough and asthmatic cough. Then by computing Pneumonic Cough Index each patient was classified as either into pneumonia or asthma. Proposed method achieved an accuracy of 90% (sensitivity = 100% and specificity = 80%) in classifying pneumonia and asthma patients. Our results indicate that cough sound carry critical information which can be used to separate asthma patients from pneumonia. Proposed technique in this paper shows potential to become an alternative for bronchodilator test in the resource poor areas of the world.

KEYWORDS :

Paediatric, pneumonia, asthma, bronchodilator, Cough, hidden- markov model.

INTRODUCTION :

Pneumonia is one of the dangerous diseases for children. In 2015, it claimed more than nine hundred thousand deaths in children under five years . In similar, asthma is the most common chronic disease in childhood. The prevalence of asthma in developing countries it ranges from 4% to 32% wherein majority of deaths occurred in low to middle income countries.[1-5]

People in low income countries, they have limited access to modern diagnosis tools. To assist the diagnosis of serious diseases such as pneumonia/asthma in such regions, The WHO have developed a basic guideline called the Integrated Management of Childhood Illness (IMCI) . According to the guideline, the clinical signs of cough and/or difficulty of breathing are the screening in criterion for pneumonia.[6-17] Fast breathing rate is a determinant of whether pneumonia exists. The diagnosis of asthma is established by the symptoms of wheezing (often with cough), fast breathing, hyperventilation of the lungs, chest wall in-drawing and prolonged expiration.

The IMCI algorithm for pneumonia diagnosis has high sensitivity (69 – 94%) but at the cost of poor specificity (67– 16 %) . Hence, IMCI leads to a high false positive rate. One major reason for high false positive rate is the overlap in the symptoms of pneumonia and asthma in the IMCI. Two recent studies on IMCI implementation in Uganda and India showed that many asthma cases were misdiagnosed as pneumonia and received medication meant for pneumonia. To address this issue, the WHO recommends a bronchodilator test in children with wheeze and fast breathing and/or lower chest in-drawing before they are classified as having pneumonia . If the symptoms disappear after the bronchodilator test the treatment is continued; otherwise antibiotic is prescribed. However, the issue is bronchodilators and their delivery systems such as inhalers or [18-24]nebulizers are expensive. They are also rare in resource-limited settings. Further, extra efforts to sterilize the bronchodilator delivery system are required to avoid the spread of infections.

In this paper, we propose a cough sound analysis method as an alternative for bronchodilator test in remote areas. Cough is a major symptom of both pneumonia and asthma. It is well known that cough sounds carry information related to respiratory diseases . One study claimed that quantitative cough analysis can differentiate healthy, asthmatic, and COPD (chronic obstruction pulmonary diseases) subjects with an accuracy of 85-90%. Our own feasibility studied indicated that cough carries vital information that can be extracted by quantitative analysis and used to screen pneumonia in remote regions.

We hypothesize that cough sounds carry vital information specific to pneumonia and asthma diseases. Support for this hypothesis comes from the Path physiology of pneumonia and asthma, the physics of cough sound generation, and our prior explorations . The outcome of this work has the potential to transform the way the pneumonia/asthma is man-aged in remote

resource-limited settings of the world.

MATERIAL AND METHODS

A. Data acquisition

The inclusion criteria for this study are cough, breathlessness, fever (temperature $\geq 37.5^{\circ}\text{C}$). Patients with at least two of the symptoms were included. Patients with advanced diseases such as cancer, droplet precautions (tuberculosis) or patients with non-invasive ventilation were excluded from this study.

The recording setup consisted of a pair of low-noise microphones (Model NT3, RODE[®], Sydney, Australia), a pre-amplifier and an A/D converter (Model Mobile Pre-USB, M-Audio[®], CA, USA). The sampling rate was set at $F_s = 44.1$ k samples/s at 16-bits/sample. [25-29]The distance between the patients and the microphone aimed towards them varied between 40 cm - 70 cm depending on the position of their heads.

B. Data set preparation

In this study, we included $W = 20$ paediatric patients diagnosed as pneumonia or asthma. To construct the dataset, the first 50 clean cough sounds from each sound recording were selected for analysis. If the number of coughs in a recording were less than 50 then all coughs fulfilling the criteria were used. Let D_S represents the total number of coughs obtained from 20 patients.[30-39]

C. Classification of pneumonia and asthma

The method to separate pneumonia and asthma subjects is a two-step process which is described below.

Step 1 – In this step a classifier was trained to automatically label each cough as either ‘pneumonic cough’ or ‘asthmatic cough’. For this, each cough event is segmented using a rectangular window of length N ms. To investigate the optimum size of rectangular window, N was varied from 20 ms to 60 ms in steps of 10 ms, with 50% overlap. From each segment, Mel-Frequency Cepstral Coefficients (MFCC) were computed to form a mathematical feature vector. The MFCCs are spectral features which approximates the auditory system behaviour by using non-linear frequency scale. They have been found useful in speech as well as cough processing. In this work MFCCs describes the temporal characteristic of cough episodes. Next, using mathematical features an automatic pattern classifier was trained to label each cough event. In this paper we used a classifier. A HMM classifier models the probabilistic behaviour of the MFCCs features in the cough episodes. To model the probabilistic characteristics of feature vector, multivariate Gaussian Mixture Model (GMM) with j components was used. To find the optimum value of j , HMM were designed with $j = [1, 2, 4, 6]$. Different sets of HMM were designed for pneumonia coughs and asthma coughs. Output of a HMM model is a Log-Likelihood (LL) score. The higher the LL , higher is the probability of cough belonging to that model. A cough was labelled as ‘pneumonic cough’ if LL score of the pneumonia HMM was higher than LL score of the asthma HMM.

Step 2 - Once all the cough events are labelled as either ‘pneumonia cough’ or ‘asthmatic cough’, following procedure in step 1, we computed Pneumonic Cough Index (PCI). Let Q be the number of coughs classified as pneumonia and T is the total number of coughs analyzed from a subject. The PCI is computed as given in .

$$PCI = Q/T \quad (1)$$

Subjects that have PCI higher than the optimum

PCI threshold (γ) are classified as pneumonia else as asthma. To compute the optimum γ we used Receiver-Operating-Characteristic curve.

D. Validation method and Performance Valuation

We used Leave One out Validation (LOV) technique to validate the method. The LOV technique involves using data from all the patients except one to train the model and data from the excluded patient to validate the method. This process is systematically repeated such that data from each subject in the dataset is used as the validation data exactly one time. To evaluate the performance of the designed models, performance measures such as Sensitivity, Specificity, Accuracy, Positive Predicted Value, Negative Predicted Value, Cohen’s Kappa statistic were computed.

RESULTS :

Dataset and clinical findings

Our study dataset consists of $W = 20$ subjects, with eight males and twelve females. The age range was one to eighteen months (mean twenty-five months). The ratio of pneumonia to asthma subjects was 1:1. The total number of coughs in the data set D_s was 738, with 461 coughs from pneumonia subjects and 277 coughs from asthma subjects. Over a sixty minutes of period, the average number of coughs in pneumonia subjects was larger (48 coughs) than that in asthma subjects (28 coughs).

FUTURE WORK :

In future work it is interesting to get cough sounds from the pneumonia and asthma patients. As we collect the cough sound from the patients, those

sounds are given as a input to the program we have developed in MATLAB. By developing Hidden Markov Model as a analyser in the program two windows are developed for the asthma and pneumonia each. With this program the new cough sound will be automatically detected[40-45]

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