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A Real Time Cough Monitor for Classification of Various Pulmonary Diseases

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***Abstract*-Cough is the most troublesome symptoms and event of illness. There are varied causes of cough such as respiratory tract infections to unrelieved conditions such as asthma, bronchitis etc. The frequency of cough is important for both accurate diagnosis and for monitoring the success of the treatment. The goal of this work is to put into use of a non-invasive and unobtrusive device that will accurately record the frequency of cough. Electromyography (EMG) is used to obtain the cough signals from the patients. The signals are recorded in real time using LabVIEW software. We have taken two commonly existing and closely related pulmonary diseases namely Asthma and Bronchitis for our work. These diseases are differentiated based on the frequency of cough and the cough pattern. The availability of a reliable and accurate method to record the extent and severity of cough thereby improves the respiratory care and management of these patients. The advantage of cough monitor is early screening of pulmonary diseases and thus proper diagnosis and treatment for patients are possible.**

***Index Terms*—Cough EMG; Asthma; Bronchitis; Frequency; Pattern; Early detection.**

I. Introduction

Cough - a common symptom forms the reason for most patients to visit the clinic. Although it protects, clears the respiratory tract and removes potentially harmful debris and secretions it's increased frequency and intensity of cough can also be harmful to the patient [1-2]. Cough is initiated by stimulation of two different classes of afferent nerves, namely the myelinated rapidly adapting receptors, and nonmyelinated C-fibers with endings in the lungs [3].

The physiological events that occur during cough are three major events:
1) Initial deep inspiration
2) Tight closure of the glottis with compression of air in the lower respiratory tract, caused largely by contraction of the abdominal muscles and
3) The sudden opening of the glottis allowing the rapid expulsion of air. It is the high velocity of the air that entrains secretions [4]. Though, there are previous works on recording cough, there is no objective system for assessing the frequency variation of cough, which can actually be used to identify or screen between symptomatically closely related pulmonary diseases. Hence, this calls for a cough monitor based on muscular movement which can truly define the respiratory status of the patients associated with cough.

II. Motivation

Cough being the most frequent symptom for almost all pulmonary diseases, the signal availability is always on the higher side be it for clinical testing or research studies. Generally we find a good number of recorders or scanners for other diseases for both screening and detection. Cough, though a common symptom, we do not observe as many instruments in hospitals which make use of this for detection or diagnostics. Additionally we find many pulmonary diseases having similar symptoms in the initial stages, which make the physicians, prescribe biochemical tests for all the pulmonary diseases having such symptoms. Hence we need a screening test to determine the test to be prescribed according to the disease doubted or detected. This puts forth a requirement for detection based on cough which is usually common in all pulmonary diseases but also variant from one disease to the other. This motivated us to develop a cough monitor combined analyzer to record the cough frequency and use the same to identify and classify the pulmonary diseases in early stages.

III. Literature Review

It is still not known if the number of coughs is a function of the severity of the disease underlying the cough or not. Initial works have been attempted to quantitatively determine cough by allotting marks/scores over a given period by the nursing staff or by the patient himself. Cough was later recorded on a tape-recorder where the mobility of the patient was restricted to the room. Then a 24 hour ambulatory cough meter to measure cough frequency was developed to compare patient-completed scoring vs. attendant-completed scores and also the visual analogue scale (VAS) to the verbal category descriptive (VCD) score. Holter monitor then evolved into a cough meter and processor. Various works were used to find the correlation between the audio and physiological signals. Yet another work focused on correlating the video signals and physiological signals measured using accelerometer as a cough meter [5-11]. There are numerous studies and publications on different types of cough monitor or ways of recording cough signals but with assumptions and limitations. The microphone signals had delay in denoting the start of a cough event when compared to electromyographic signals. This is due to the fact that cough originates with initial deep inspiration (which is a part of cough) that is not taken into account in the audio or video signals but does gets into recording when EMG signals are recorded. Also accelerometer has

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less precession when compared to EMG recording. Thus in this project work we focus on using EMG recording for cough meter for pulmonary disease screening. Though there are varieties of works done with cough monitor or meter, there existed no study related to screening or identification of pulmonary diseases based on cough frequency or count.

IV. Materials and Method

Materials include pre gelled surface electrodes, EMG setup (detector, amplifier, rectifier and filter), DAQ card (NI instruments), LabVIEW and MATLAB. The electrodes are positioned as shown and are considered to reflect the activation of the abdominal muscles [12, 13, 14].

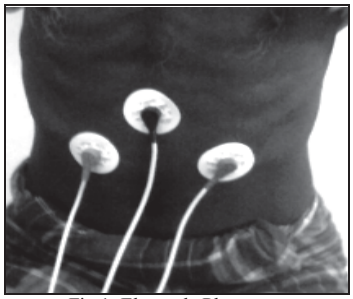

Fig.1. Electrode Placement

A. Recording Setup

The setup has an EMG (Electromyography) amplifier (with a DC offset of 4V) to obtain the cough signals from the patients. This acts as a differential amplifier that detects the potential differences between the electrodes and cancels external interferences out. The amplified signals are rectified, filtered and the output is given to the analog input terminal of DAQ card and displayed in real time using LabVIEW software and is also stored. Recording was performed for a period of 2 minutes at the rate of 1000 samples per second from patients having Asthma and Bronchitis and normal subjects. The diseases are differentiated based on the frequency of cough and the cough pattern after processing in MATLAB and plotting them.

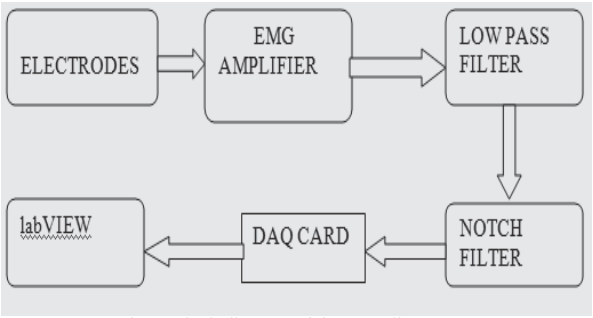

Fig.2. Block diagram of the recording set up

B. Process of recording

A LabVIEW- VI was built with the desired specifications to record the cough EMG signals. The total number of acquistions and the number of points per acquisiton are set to 100 respectively. The sampling rate is set to 1kHz. A time strap is included for recording the signals for a specified time interval. The signals recorded are saved in the text format for further analysis.

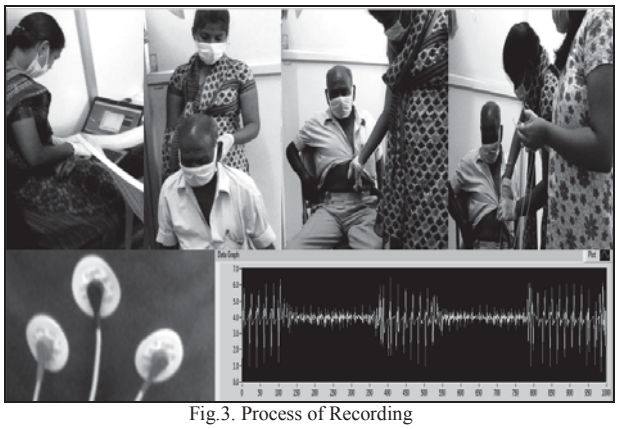

Fig.3. Process of Recording

C. Data Conversion using Visual Basics

In text format the continuous values are stored as a string in notepad, which requires a conversion for processing in MATLAB. So a code was developed using VB(Visual Basic) Software to convert a set of string of data values into a single column of data. The single column datas are saved in .txt format.

V. Processing

A. Filtering

MATLAB software is used here in this project for signal processing application. The EMG signals from patients are filtered with the filter objects generated by the help of fdatool. The patient signals are then plotted and viewed using the same. Filter design specifications for a Notch (Bandstop) filter includes sampling frequency (F_s) as 1000Hz, cut off frequencies (F_{c1} & F_{c2}) as 48Hz and 52Hz respectively and the design method as IIR Butterworth [14, 15]. This removes the power line interference from the raw EMG signal [16].

B. Coding

Recording was for period of 2 minutes (i.e. 120 seconds) at the rate of 1000 samples per second. Hence 1, 20,000 values are obtained and plotted for each of the patient signals.

Example:

```
samplingintr=.001; % denotes sampling interval
time=1:120000      % time vector
out=time*samplingintr % defined variable out
% Filtering using band stop filter Hd of cutoff (48-52)Hz
a=filter(Hd,p1);
% filter function used to filter out signal p1
figure(1);
plot(out,a);
% plot of filtered patient signal
xlabel('Time(in seconds)');
ylabel('Amplitude(in Volts)');
title('Patient name-age');
```

VI. Analysis and Results

A. Pattern and nature

The processed signals of each disease tested were found to exhibit a unique pattern. The contractions and relaxations in the signals represent the muscular potential that runs high due to the muscle contraction during cough and goes low due to relaxation during normalcy respectively.

Chronic bronchitis signals were found to have the maximum number of cough instances. Each cough event (i.e. initiation and termination of cough) is found to have a minimum of three coughs or cough instances. Asthma signals were found to have lesser number of instances or not more than one cough instances in each cough event. Normal cold and flu cough pattern was quite different from the other two having exactly one cough instance that makes up one cough event.From this we could infer that chronic bronchitis signal has lesser number of cough events with more cough instances, while asthmatic cough signal has more single cough events with lesser number of cough instances per event. While normal cold and flu cough signal has exactly one cough instance per cough event.

B. Counts and frequency

Chronic bronchitis signals had the maximum cough instances ranging from 16 to 34 times. Asthma signals had cough instances ranging from 10 to 14 in number and normal cold and flu cough count ranged from 3 to 6, which is the lowest of all. From this we infer that chronic bronchitis patients have a higher number of coughs when compared to asthma and cold & flu patients.

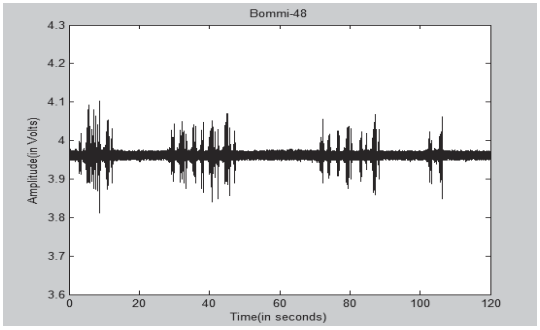

Fig.4. Signal Pattern of Bronchitis Cough

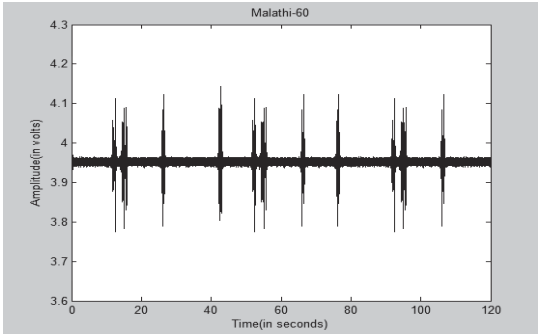

Fig.5. Signal Pattern of Asthma Cough

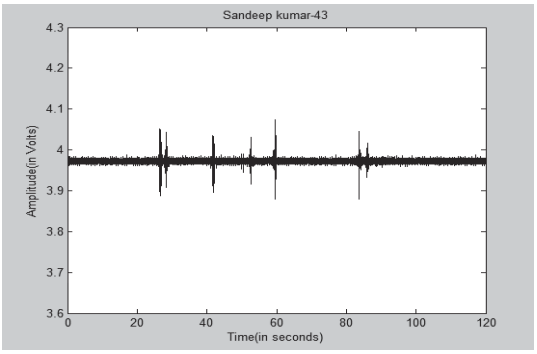

Fig.6. Signal Pattern of Normal Cold and Flu Cough

C. Observation

We observed the cough signal recorded through the EMG signal from patients' body, mainly in abdomen region. The variation in the amplitude and frequency i.e. cough count from patients to patients was seen. The amplitude variation can be related to the muscular potential that arises due to the contraction and relaxation of the muscles [17]. Generally this is found to vary from patient to patient according their muscle and their built. The count variation for a particular disease is found to fall within a range which can be used as an identifier for that disease.

Our observation was over two minutes and was limited to two common closely related pulmonary diseases namely Asthma and Chronic Bronchitis, and comparing it with the normal cold and flu cough count. The range was found to vary quite widely from diseases to diseases and with the normal cold and flu cough count. Additionally unique pattern was represented by each diseased cough and the normal cough.

D. Findings

These conclusions are solely based on the cough count variance that was observed from the patients' cough. This variance in cough count was manually found out based on the pattern observed for each disease.

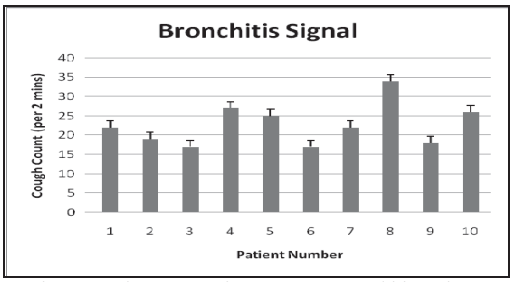

Fig.7. Cough Count Variance among Bronchitis Patients

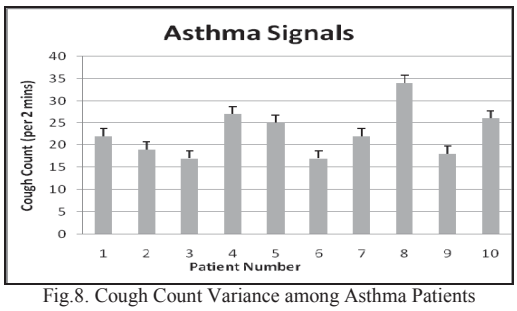

Fig.8. Cough Count Variance among Asthma Patients

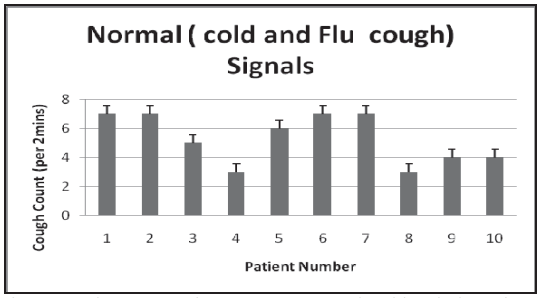

Fig.9. Cough Count Variance among Normal Cold and Flu Patients

TABLE I. Mean Cough Count of Various Signals

Signals	Mean
Bronchitis	**22.6 ± 5.13**
Asthma	**12.2 ±1.24**
Normal	**5.3 ±1.61**

VII. Future Scope

This project can be extended to various other pulmonary diseases which would be of great help to doctors. This project if worked on more detailed, would serve as a screening test that would help doctors to customize the test they may have to perform on the patients. Pattern recognition and artificial neural network can be applied to differentiate the same, which would make the system more powerful. Also, concept of correlation or coherence between the diseased cough and the normal cold and flu cough could be used as a differentiator to make the screening precise and accurate. Additionally, automating these would less stress the technicians and doctors.

VIII. Conclusion

Thus this project on cough monitor for classification of various pulmonary diseases is based on the pattern and count of cough, which when manually analyzed and counted respectively gives us the idea of disease which may be present. This instrumentation setup would record the patients' cough signal through EMG electrodes from the abdomen region and document the EMG signal in a data form, which has to be processed offline in MATLAB. Finally looking at the signals' pattern and counting the number of cough instances per event and number of cough events, we classify the signal as Asthmatic or Bronchitis or Normal cold and flu cough. Thus a possible screening test for differentiating and identifying closely related pulmonary diseases having similar symptoms was made possible with this project.

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