Detection of COVID 19 and Pulmonary Fibrosis using Portable Static Compliance Meter

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Abstract: Compliance is one of the important parameters that is used in invasive patient monitoring systems to diagnose major lung diseases which cannot be tracked from scans and blood tests. Unfortunately there are some limits like it cannot be used for continuous monitoring purposes due to large power consumption and heavy weight. Hence it is important to develop a non invasive and lightweight compliance meter which can be used for continuous monitoring purposes. With respect to COVID pandemic, there is no proper tool to diagnose sars directly. Hence measuring compliance can help us know the presence of sars as well as intensity through which the virus has affected the lungs. This paper proposes the design and implementation of a low cost, light weight and noninvasive compliance meter. Two sets of assumptions are taken to implement the same. The first one is to measure the compliance of the healthy person and the succeeding one is to measure the compliance of the abnormal patient. The healthy wave will be made in the software and the abnormal wave will be compared with the ideal values to give the final output. Since a comparative method is followed, the accuracy and efficiency of the meter is increased. Alsoself calibration is achieved. This prevents replacement of the product then and then and there. The data thus collected will be transferred to the nurse station for data visualization. This promotes an alert system and reduces human labor.

Keywords: Compliance, Simulation, Pressure Vs Volume, Bolt, Comparison, Compliance Degrees.

I. Introduction

There is an immense improvement in the ventilator systems used mainly in intensive care units and critical care units. Compliance consists of two types - static and dynamic. Static compliance refers to the stable compliance measurement whereas dynamic refers to unstable compliance measurement. The former is used in tracking the lung status in case of TB and other noncausal disorders. The latter is used to diagnose pathogen related lung disorders. But due to expenses and high power consumption, continuous monitoring becomes a challenging task. According to MDR regulations for medical devices, validation becomes a major challenge in case we try to reduce the size of the device. But during an outbreak like COVID, non invasive and portable compliance meters are much needed ones. Hence accuracy testing and clinical trials becomes a restriction. The proposed meter can be used in non invasive ventilators or in any roadside booth as the size is very much reduced. Lung monitoring of those patients post COVID becomes a tedious job as no tool is developed as far as now except for temperature measurement.

The rest of the paper is organised as follows, Section 2 contains the related works. Section 3 is presented with comparative technicalities of traditional and proposed compliance meters. Section 4 contains the simulation results. Section 5 is dealt with the accuracy testing and clinical trials. Section 6 is dealt with future work and enhancement followed by conclusion.

II. Related Works

Amy D. Droitcour, [1] worked on a clinical non invasive respiratory management system for patients who are in need of artificial respirator. She made a comparative study with 56 patients who had similar conditions but of different age groups. Hence she figured out that the same system cannot be used for all the age groups. This was one of the major problems in wearable devices.

Haipeng Liu, [2] tried to develop the traditional respiratory device system making it eligible for all the age groups. He extracted the RR using other physiological signals from the human body. After several clinical trials, he came to know that extracting other signals required massive medical equipment and patient's cooperation as his method was invasive in nature.

Carlo Massaroni, [3] implemented contact based respiratory management systems which involved oxygen electrodes and chemical electrodes. The main principle behind his system was the transfer of gaseous molecules from one electrode to another givind a difference in pressure. This difference will be synced with the person's breathing pressure and hence the RR can be extracted. This method was limited because of the size and accuracy of the device mechanism.

Rasa Izadnegahdar, [4] developed the first non invasive wearable respiratory measuring device which can measure the parameters like lung capacity, tidal volume and reserve volume of the lungs. She took a systematic

approach towards the existing tools available and made a device to overcome all the limits. But the model was expensive as it used high level inbuilt and internal sensors which put a halt to continuous monitoring.

Ian Smith, [5] developed a thermal based respiratory system which can measure the RR of the person. The major drawback with the system was that the imaging part of the device must be replaced after every use and it was quite an expensive and time consuming process wholly.

From the above analysis and references, we came to a conclusion that there is no wearable tool which can measure the compliance degree of the patient non invasively, light weight, cost effectively. There is no proper alert system installed with the device and cannot be promoted for the sake of continuous monitoring systems. The main aim of a diagnostic tool when it comes with respect with COVID is that it should be alerted, non invasive and portable and cost effective.

III. Comparative Technicalities of Traditional and Proposed Compliance Meters

A. Traditional Compliance Meter

The traditional compliance meter consists of an external spirometer connected to the spirometer wall. The spirometer wall is connected with a mouthpiece through which the patient will be asked to inhale. The pressure thus exerted will be measured and the resulting tidal volume will be produced. Once the device is used, it cannot be used by the other person as the mouthpiece alone cannot be replaced due to design. Hence the whole device must be replaced for making it reusable. The pressure measurer loses its calibration over a period of time and hence accuracy cannot be achieved over a period of time.

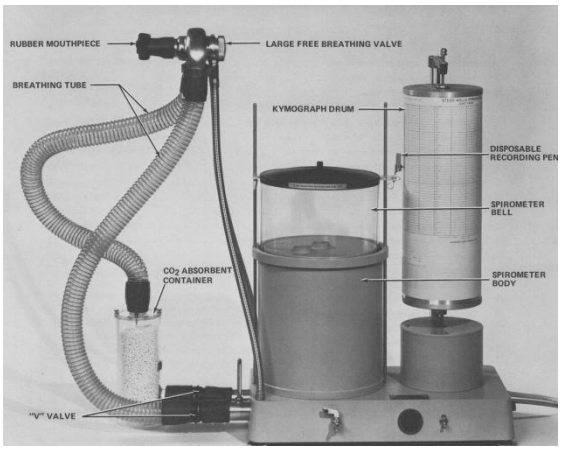

Fig 1: Traditional Compliance Meter

This meter is not suitable for ventilator diagnostic purposes due to its large size and heavy power consumption.

B. Proposed Compliance meter

The proposed compliance meter has ideal wave inbuilt in it. The ideal wave is measured by using Masco's Law. This step is followed by the measurement of compliance degree in the patient using sensor operation and the change in volume. The results are compared with the ideal characteristics and the output is produced. Also since the device works comparatively, self calibration is achieved every time the output is compared with the ideal waves.

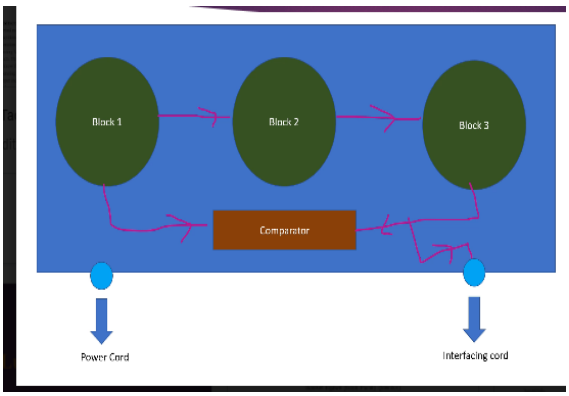

Fig 2: Proposed Product Package

IV. Simulation Results

A. Ideal Wave Measurement

As part of measuring the ideal wave, an NTC thermistor will be fixed inside a nebulizer mask. Three thermistors are used here in order to achieve clinical accuracy. Once the patient breathes through the mask, the temperature changes during the inspiration is converted into pressure using a thermistor. This change is processed using Masco's law and the final result is given as pressure Vs volume graph.

Fig 3 : Nebulizer mask with thermistor fixed

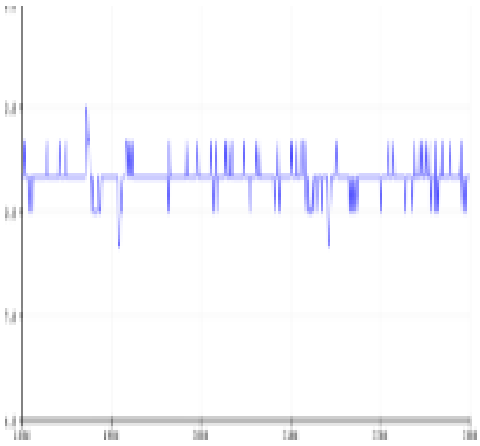

Fig 4 : Ideal wave. X axis: Time (s), Y axis: Compliance Degree (no unit)

B. Measurement in Patient

For this case, we have considered a dummy model with a bottle filled with a known amount of water which has a balloon blown with a known amount of air. A clinical volume sensor will be placed inside the balloon and a clinical pressure sensor will be placed in the bottle neck. The volume and pressure sensor are connected via an arduino hub library wirelessly. A syringe will be placed on the side of the bottle. Its purpose is to inject and extract water from it. This is analogous to person inhaling and exhaling. Suitable algorithm is done and the graph for pressure Vs volume is obtained by changing the volume of water via injecting and extracting water from the bottle. Here the air volume inside the balloon will be constant throughout which is analogous to reserve volume in the lungs.

Fig 5: Dummy Model

For every change in the volume given as input, the graph is produced between pressure and volume which is very much different from the ideal wave. Along with the sensor, an indicator will be placed. If there is red light, it means that the patient's breathing is not active i.e it's stopped. If there is orange light, it means that the values are varied from the critical and threshold values. This promotes an alert system.

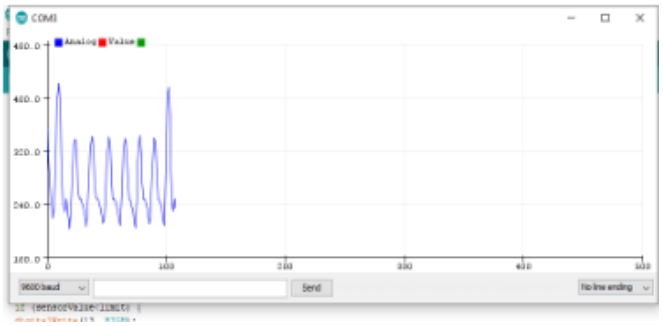

Fig 6 : Patient's Compliance graph, X axis: Volume (ml), Y axis: Compliance Degree (no unit)

C. Data Visualization and Feasibility

Now that the data are collected, these can be transferred to the nurse station using IOT. A bolt module can be used with the product to transfer the data immediately and continuously. Thus the doctors can view the data at any time by visiting the dashboard in bolt. One single bolt module can handle 56 such compliance metres and hence the product is feasible for large scale marketing and consumption.

D. Threshold Values

Inspirational capacity : 3500 ml

Functional Residual Capacity : 2300 ml

Vital Capacity: 4300 ml

Total Lung Capacity : 5300 ml

Compliance Degree : 500 - 550

Since the proposed product is very much effective in all criteria compared with the existing product, the product is sustainable.

V. Accuracy Testing and Clinical Trials

A. Accuracy Testing

Inorder to check for the accuracy of the proposed product, a professional spiroscope was used and tested with the patient. The results from the spiroscope and the proposed product was compared and it was found that the accuracy was near cent percentage.

Fig 7: Professional Spiroscope

B. Clinical Testing:

The proposed product was tested with 3 people and appropriate results were obtained from all of them. This product was readily recommended by the doctors of global hospital, Chennai.

VI. Future Work and Conclusion

A. Future Work

The data collected so far is in the numerical form. This can be converted into binary form using suitable converters. This can help in having a patient's record.

B. Regulation for medical devices

The product can be exposed for official clinical trials under MDR regulations to get the no objection certificate. This can later be given for market segmentation

Thus a non invasive, light weight, cost effective, alerted, portable compliance meter was implemented and tested for accuracy.

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