Portable Health Monitoring System using Respiration and ECG Sensor

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Abstract: Chronic obstructive pulmonary disease (COPD), a disabling combination of emphysema and chronic bronchitis, relies on spirometric lung function measurements for clinical diagnosis and treatment. Because spirometers are unavailable in most of the developing world, this project developed a low cost point of care spirometer prototype for the mobile phone called the “TeleSpiro.” The key contributions of this work are the design of a novel repeat use, sterilisable, low cost, phone- powered prototype meeting world user requirements. A differential pressure sensor, dual humidity/pressure sensor, microcontroller and USB hardware were mounted on a printed circuit board for measurement of air flow in a custom machined lathed respiratory air flow tube. The embedded circuit electronics were programmed to transmit data to and receive power directly from either a computer or Android smartphone without the use of batteries. Software was written to filter and extract respiratory cycles from the digitized data. Differential pressure signals from Telespiro showed robust, reproducible responses to the delivery of physiologic lung volumes. The designed device satisfied the stringent design criteria of resource-limited settings and makes substantial inroads in providing evidence-based chronic respiratory disease management.

Keywords: Mhealth, Spirometer, Point Of Care Health Delivery, COPD, Asthma, Lung Volume, Low-Cost, Global Healthcare.

I. INTRODUCTION

Wireless network penetration into developing world geographic areas have made mobile health care of interest in resource-limited settings [1]. Mobile phone portability, USB communication, data storage and the ability to support external hardware to collect and store medical data enables a new way to address the growing global burden of chronic disease [2]. Chronic lung disease in the developing world is both staggering and growing as a result of increased air pollution, tobacco use, indoor cooking and workplace exposures. Chronic obstructive pulmonary disease (COPD), which involves destruction of lung elastic recoil with concomitant chronic bronchitis, results from these inhalational exposures and affects 210 million people globally [3]. Spirometry is the foundation of these tests, and the value of using specific spirometric (ventilatory flow) measurements of COPD lung changes is well established, especially when a clinician must distinguish between various aetiologies of chest pain or cough symptoms [4]. A variety of measurements can be obtained and interpreted from spirometry; however the forced expiratory volume in one second (FEV1) divided by the forced vital capacity (FVC) over the entire exhalation, un- masks obstructive changes to the patient’s lung parenchyma [5].

The forced vital capacity (FVC) is the difference between the volume in the lungs at full inhalation and the residual volume of air left in the lungs after maximal exhalation. The FEV1/FVC ratio reveals whether there is smaller airway collapse within the lung also known as obstruction. Spirometric lung function tests measured by a spirometer remains a cornerstone of COPD clinical care. Developing a low cost device would thus greatly improve management of COPD, asthma and lung diseases by providing an objective basis to diagnose and manage symptoms. Several low cost spirometry prototypes in the literature have made advances in design [6] [7] [8] [9]; however none of these prototypes have been used in published clinical trials, do not adhere to international accuracy requirements and cost more that $80 a piece. Implementing spirometry in resource-limited settings requires consideration of price point, sterility, user interface, power supply, dearth of skilled clinicians and ability to generate useful dynamic lung flow data. Per capita health spending in Africa and South Asia is less than $40 per year, far less than the cost of most spirometers [10]. However, even a cost of $15 per spirometer could be justified if amortised over several years given the benefit of keeping chronically ill patients out of the hospital. The dearth of adequate low cost spirometers represents an opportunity for substantial design innovation and for employing more sophisticated signal processing techniques on spirometric data. The aim of this study is to develop a spirometer which connects to a mobile phone and that costs less than $15 while also meeting internationally accepted clinical requirements [11].

II. METHODS

The Telespiro design required several related hardware (breathing tube, electronics) components and software programs (microcontroller, mobile platform) for device...
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operation on a mobile smartphone handset. Pneumotachometric pressure based flow detection was selected because of its widespread clinical use as well as the intrinsic cost and calibration limitations of ultrasonic and hot-wire anemometry based air flow detection. A symmetric tube design (see figure 1) with a narrow middle section and removable disc element was machined from medical grade autoclavable polyoxymethylene. The disc was designed in order to avoid stationary filter elements in the air stream that could collect infectious particulate without possibility of cleaning. This is of utmost importance in the world’s poorest areas wherein people suffer from disproportionately high levels of multi drug resistant tuberculosis, pneumonia and parasitic infection. Because international spirometer standards set by the American Thoracic Society (ATS) and European Respiratory Society (ERS) [11] dictate a maximal airflow resistance value (150 Pa=L=s) and minimum accuracy for device approval, the diameter of the narrowest part of the tube (28mm) and length (120mm) was selected to provide resistance of 148 Pa=L as calculated by from the Pouseille equation

\[ R = \frac{8 x}{r^4} \]  

(1)

The small disc (a removable piece of solid material with holes large enough to clean with a small brush, water and bleach or soap) fit into the tube constriction. Similar to a Fleish pneumotachometer, the disc was designed with multiple identical holes to create a sufficient pressure differential. Collecting spirometric data from the Telespiro tube required portable low cost electronic components connected to and drawing power from a mobile phone. Though a wire- less data transmission would enable easier use, Bluetooth transmitter costs made a wireless device prohibitive given per capita health spending in most developing nations. Without a physical connection to the phone, a wireless device would require an external power supply. More importantly, wireless pairing a medical device creates the potential for data loss or incorrect usage. A USB cable was thus required, allowing easy and intuitive connectivity to USB on a phone or computer. The electronics components and sensors were mounted on a custom circuit board (see figure 2) for connection to the machined respiratory tube and phone. The soldered PCB sensor unit was roughly the size of a USB flash drive, small enough to fit inside the designed breathing tube itself for transport. The total bulk manufacturing cost of the final device was estimated at $11.75, which included all Telespiro pieces excluding the phone handset itself.

III. BLOCK DIAGRAM

Design of low cost health monitoring system using Air flow sensor, Body temperature sensor and ECG sensor. To monitor breathing rate we are using air flow sensor. It presents a remote monitoring system for electrocardiographic and temperature signals. The system consists of a hardware module for acquisition, a GSM transmission module and finally a displaying module (PC) for viewing analog signals .The system was assessed by testing different patients with the support of a medical doctor, obtaining a positive performance. The Data from controller to mobile will be sent through GSM module and doctor can view and accordingly he can diagnose the patient (fig 1).

IV. RESULTS

Initial Telespiro testing was performed in MATLAB (Mathworks, Massachusetts, US) on a serial to USB computer interface before implementation on a mobile platform. Using a sampling frequency of 250Hz, all signal data were recorded from a single subject breathing at tidal volume into and out of the flow tube end with the resistive disc in place. The subject’s mouth was positioned on the Telespiro tube inlet. After a few breaths, a maximal respiratory effort was performed as would be done to obtain a FEV1/FVC ratio in clinic. A7kPa 7kPa a differential pressor sensor was selected because the maximal expiratory maneuver and tidal volumes (fig 2).
V. CONCLUSION

Telespiro is a novel low-cost spirometer prototype for point of care respiratory testing in resource limited settings. Differential pressure signals from Telespiro showed robust, reproducible responses to the delivery of physiologic lung volumes. The designed device satisfied the stringent design criteria of resource limited settings, ERS/ATS criteria and will be ready for more robust trials and regulatory approval testing. The substantial improvements made in this project to meet resource-limited setting requirements include: low price point of less than $12 per device in manufacturing with easy to obtain materials for assembly.

VI. REFERENCES