Low-cost Portable Ventilator Design for Underdeveloped Regions

Rui Wang* and Fangzhou Xia†
*High School Affiliated to Renmin University of China, China, ericwangrui451@gmail.com
†Massachusetts Institute of Technology, USA, xiafz@mit.edu

2021 IEEE Integrated STEM Education Conference (ISEC) | 978-1-6654-1383-1/21/$31.00 ©2021 IEEE | DOI: 10.1109/ISEC52395.2021.9764128

Abstract

The coronavirus disease (COVID-19) pandemic has significantly challenged the world in many ways especially for the medical sector. One of the most important challenge is the shortage of ventilators for COVID-19 treatment. In 2020, nearly one hundred million people have been infected globally, where at least ten percent of the patients may develop severe respiratory distress that require ventilators for treatment. Since conventional ventilators are high-end medical equipment not commonly used, the stock numbers are insufficient as cases surge. For example, around 2000 people share one ventilator in the U.S at the beginning of the pandemic. Such a shortage is even severer in underdeveloped countries such as the Central African Republic where millions of people need to share a single ventilator. On the other hand, ventilators are vital to increase the survival rate of patients in critical conditions. As the coronavirus damages lung function and impedes oxygen absorption, ventilators assist breathing by pressurizing air into lungs to maintain the blood oxygen concentration. Existing ventilators are not designed for handling the pandemic especially in third-world countries. High-end ventilators typically cost more than $10k per installment and cannot be easily produced. On the lower-end, Bag Valve Mask (BVM) requires manual pumping that yields high risk of infection. Researchers at MIT has developed automated BVM-based ventilator. However, the important functionalities for patient biometric sensing and doctor alarming are still missing from previous designs. In this poster, we present our solution to this challenge by developing a low-cost portable ventilator with three main highlights. First, with $300 target budget, the system can be produced in large quantities for use at temporary mobile cabin hospitals. Second, a patient monitoring system for blood oxygen and electrocardiogram are included with wireless alarms to notify doctors in case of emergency. Third, the exhaled air will be disinfected by specialized filter to reduce the risk of cross infection. The oxygen supply mechanical subsystem design is centered around a BVM compressed using a mechanism driven by a stepper motor. Supplemental oxygen can also be added from portable canisters. The electrical subsystems are primarily based on the Arduino microcontroller platform for both oxygen supply control and sensor signal processing. A custom instrumentation-amplifier-based electrocardiogram circuit and an infrared oximeter sensor are designed to measure patient biometrics. A wireless communication scheme is realized with Bluetooth modules for remote monitoring and can operate as an alarm to the doctor. The assembled prototype is currently capable of supplying oxygen to normal adults with a lung capacity of 6000 ml. It can also conduct simple measurement of heart rate and blood oxygen concentration with remote monitoring. The on-going tasks involve selecting exhaled gas disinfecting filter and processing signals to identify abnormal biometrics. Additional work on improving the portability of the design with battery operation is also planned. We hope this affordable open-source design can help underdeveloped countries overcome the current challenges and be better prepared for future pandemic crisis.