PORTABLE VENTILATOR AS AN AT-HOME RECOVERY SOLUTION

BACKGROUND
A ventilator or “breathing machine” is a device that is used to assist breathing in patients with impaired lung function. With the onset of the COVID-19 pandemic, ventilator shortages in the United States and worldwide have become a pressing issue. Estimates of available ventilators range from 60,000-160,000 in hospital inventories, with varying levels of functionality within that group [1]. Furthermore, most ventilators available for use in hospitals are non-portable and their extended use fills hospital beds that have also faced shortages throughout the pandemic. Standard ventilators require patients to stay in the hospital for long durations, preventing doctors from sending their patients home with solutions for the long term. Between the need for beds and shortages in ventilators, beds in some hospitals reached full capacity in the height of the pandemic [1].

METHODOLOGY
Tidal volume delivery via a pump-actuated water column was posited as a solution to mechanically assist patient inspiration. The pump schematic, shown in Figure 1, displays the full flow circuit along with control elements, including unidirectional pumps and valves. Inspiratory and expiratory components of breathing are assisted by raising and lowering a water column respectively to displace a variable tidal volume at a necessary flow rate (and thus breaths per minute) according to the patient’s weight and condition. For inspiratory measurement against a control reference, BioPac instrumentation is used, with a tidal volume calibration shown in Figure 2.

RESULTS
MATLAB tools were used to sweep through a variety of applicable tidal volumes and determine floor and ceiling values to define ventilator flow rate and inspiratory pressure requirements and respective water column heights. Tidal volumes, or inspiratory volumes delivered to the lungs of the patient, correspond to a relationship of 6 mL/kg [2]. An evaluation of maximum calculated inspiratory pressures for patients with required tidal volumes of 125 to 400 mL at the ceiling value of 15 BPM is shown in Figure 3 for patient weights of up to 66 kg:

DISCUSSION
With the current proof-of-concept, demonstration of inspiratory and expiratory flows has been achieved by powering pumps in sequence. A power supply powers the motor controlled inspiratory and expiratory flow-rate pumps respectively, modelling a patient breathing at 8 BPM with a tidal volume of 350mL. Pressure and flow rate analyses led to the acquisition of new pumps to supply the flow parameters necessary to meet the full range of physiological requirements for the ventilator design. Work is underway to add valves to toggle inspiratory and expiratory states in airflow. A video demonstrating inspiratory flow is seen in Figure 4.

REFERENCES

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