The Faculty of Life Science Engineering's #shareresources4healthcare Challenge "Rapidly Manufactured Ventilator Systems: Engineers Strike Back"

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Abstract— Due to the lack of industry-grade mechanical ventilators resulting from the SARS-CoV-2 circumstances, the hospitals find themselves in a pressing need for alternative solutions. Initiatives from all over the world have emerged and contributed with innovative designs to the effort of developing rapidly manufactured ventilator systems. Such designs are ranging from simple low-cost portable mechanical ventilators to more complex versions. The goal is clear, design a low-cost, simple, easy-to-use and easy-to-build ventilator that can serve the patients, in an emergency timeframe. We are contributing to these global efforts by introducing a #shareresources4healthcare Challenge at the University of Applied Sciences Technikum Wien. This challenge focuses on the need to enhance initial patient diagnostic assessment and the lack of mechanical ventilation devices.

Keywords— Fast prototyping, mechanical ventilators, respiratory parameters, assistive ventilation modes

I. Introduction

Cyclical occurrences of viral diseases have become a significant public health concern worldwide. Viral epidemics caused by the severe acute respiratory syndrome coronavirus (SARS-CoV) from 2002 to 2003, and H1N1 influenza in 2009, have been recorded. In 2012 Middle East respiratory syndrome coronavirus (MERS-CoV) was contained with 2 494 confirmed cases. Currently, the world is facing the 2019 novel coronavirus (SARS-CoV-2) [1],[2].

RNA viruses such as coronavirus are highly contagious and therefore spread rapidly from human-to-human in close contact. The transmission through respiratory droplets from coughing and sneezing is thought to be the primary mechanism of the infection. Additionally, prolonged exposure to elevated aerosol concentrations in closed spaces is also a likely pathway of virus transmission [1].

The common clinical manifestation of SARS-CoV-2 fever (88.7%), cough (67.8%), fatigue (38.1%), sputum production (33.4%), shortness of breath (18.6%), sore throat (13.9%), and headache (13.6%) [3]. Most patients have a good prognosis while the disease tends to progress faster and cause complication in elderly people. Severe cases of the disease are accompanied by respiratory failure that requires mechanical ventilation. [4].

II. Tasks

The key tasks of the Rapidly Manufactured Ventilator Systems: Engineers Strike Back challenge are as follows:

A. Overall Goal of the Project

Development of the Rapidly Manufactured Ventilator Systems

- To research and describe the emerging solutions for rapid ventilator design
- To compare the solutions a) one to another b) to commercial ventilators
- To access and define safety considerations and testing requirements for the device to be used in the emergency environment
- To suggest improvements, design optimization, additional safety mechanisms
- Key Ventilator Specifications adapted from [5].

B. Specific Goal Definition

- The minimum controllable parameters to ventilate a patient include:
    - **Breaths per minute** (BPM): between **8-40 BPM**
    - **Tidal Volume** (TV) between **200 – 800 mL**
    - **I/E Ratio** (inspiratory/expiration time ratio): recommended to start around 1:2; best if adjustable between range of **1:1 – 1:4**
    - Assist Detection pressure. When a patient tries to inspire, they can cause a dip on the order of 1 – 5 cm H2O, with respect to PEEP pressure (not necessarily = atmospheric).
- Airway pressure must be monitored
    - Maximum pressure should be limited to 40 cm H2O at any time; Plateau pressure should be limited to max 30 cm H2O
    - The use of a passive mechanical blow-off valve fixed at 40 cm H2O is strongly recommended
- Clinician require readings of plateau pressure and PEEP
- **PEEP of 5-15 cm H2O** required; many patients need 10-15 cmH2O
- Failure conditions must permit conversion to **manual clinician override**, i.e. if automatic ventilation fails, the conversion to immediate ventilation must be immediate.
- **Ventilation on room air is better than no ventilation at all**. Blending of oxygen and air gas mixture to adjust FiO2 is not important in an emergency scenario. It is certainly nice to have that ability and can easily be implemented with a oxygen / air gas blender that some hospitals already have.
- Covid-19 can get aerosolized (airborne), so **HEPA filtration on the patient's exhalation is required or between the ventilator unit and the patient (at the end of the endotracheal tube)** to protect clinical staff from certain infection. In-line HEPA filters can usually be purchased alongside manual resuscitator bags.
- Heat and moisture exchanger should be used in line with the breathing circuit.
- Failure conditions must result in an alarm.

This is a minimal requirement set for emergency use. Equipment designed for more regular use, even if for emerging markets, will require additional features to be used on a regular basis.

III. The Greater Good

Information exchange about the Rapidly Manufactured Ventilator Systems

- To design an adjustable and searchable database system capable of storing information about Rapidly Manufactured Ventilator Systems.
- To develop a structure of the Rapidly Manufactured Ventilator Systems (RMVS) Database.
- To implement prototype of the RMVS Database.
- To test and interconnect the RMVS Database with existing solutions.

References

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