Authors response to editors remarks for “VentMon: An Open Source Inline Ventilator Tester and Monitor”

Dear Editors,

We thank the reviewers for the useful observations. We have attempted to address each of them as explained in-line below. Italicized text is text actually added to the paper.

Editor:

In context section

- it would be good to cite the OS ventilator projects that could benefit from this work that came out in the second half of 2020 in the peer reviewed literature.

This is a valuable point. I have tried to address it by adding several new references and the following paragraph:

“Although it is beyond the scope of this paper to review or even comment on ventilation projects, a number of pandemic response ventilators have been reported on recently which seem to be candi- dates to benefit from the VentMon, if only because of its flow-sensing and oxygen sensing capabilities (most have pressure sensors in place) [6, 10, 3, 21, 2]. Although most published reports include bench-top testing, this may have been done with an instrumented test lung which is not continu- ously available to the development teams as a VentMon might be. Additionally, most of the teams mentioned in a report on open source teams[4] could make use of a VentMon.

Reviewer #1: Minor comments only:

- The word "airway" typically refers to either (1) a device such as laryngeal mask or endotracheal tube or (2) the patients mouth pharynx and larynx. I believe the term the authors seek is "breathing circuit" or simply "circuit".
    - *Lines unchanged:*
        - *184*
        - *603*
        - *670*

        - *706*
        - *64*
    - *Changed*
        - *151*
        - *329*
        - *542*
        - *710*
    - *Fixed some instances of “airway” where appropriate*

- On sanitation, ventilators typically use valves to control the direction of flow hence avoiding the need to sanitise delicate sensors. Any sensor in the inspiratory limb will remain clean, whereas any contamination reaching the expiratory limb sensor will not be able to return to a subsequent patient.
    - *We thank the reviewer for this insight. The ventilator remains used in a room that may be exposed to the virus, but this insight allowed us to clarify the text by substituting: “Although the intended use is on the inspiratory limb of the breathing circuit, it may be exposed to air-borne virus unless its air input is sanitized.” for the sentence: “Use on a human patient would therefore require it to be disposed of immediately.”*

- Bottom of page 19 should say "browser" not "brower"? - *FIXED.*
- It would be useful to change "The VentMon spews a LOT of data out on the serial port in the PIRDS format." with an actual numeric quantification eg "The ventmon outputs 2000 20 byte records per second " or somesuch.
    - *FIXED -- Changed to “The VentMon outputs about 80 records a second of data out on the serial port in the PIRDS JSON format, publishing pressure and flow data at about 40Hz. (Addtiional data, such as temperature and humidity, is configurable output about every 20 seconds. Each record contains about 35 characters.“*

- Finally I should note that I am a clinician not an engineer so I am unable to comment on much of the paper. However, I can attest to the device being a valuable contribution to the opensource effort to create pandemic ventilators.

Reviewer #2: The following is a review of "VentMon: An Open Source Inline Ventilator Tester and Monitor." This is an interesting and timely project which presents an open-source solution as an alterative to more expensive ventilator testing equipment. More than sufficient details are given to recreate this device. The construction steps are well-described. However, this manuscript would benefit from additional descriptions of the testing of the device.

I have the following comments:

Hardware in context

- Although many people likely know what a BPAP and PAPR devices are, it would be helpful for unfamiliar readers if these abbreviations are defined at first use.

We have expanded these definitions in the first use.

Hardware description

- It would be clearer to the readers if you referred to the graphical abstract during this section.

We have added references to Graphical Abstract and the VentDisplay screen shot as below:

"The VentMon plugs directly into a standard 22mm adult airway. As air or medical gases pass through the VentMon, it records flow and pressure, temperature, humidity, and fractional O_2 at rates of 25 Hz to once per minute depending on the measurement. When placed in the breathing circuit between a ventilator under test and physical test lung ***as shown in Figure 14****, this data is sent to a public data lake [8] using a clearly defined respiration standard [7]. This data can be graphically rendered either live or statically to provide a display that is typical of the clinical display of advanced ventilators* ***as shown in Figures 14 and 15****. This functionality is similar to that of commercially available test lung devices, which tend to start at USD$10,000.*

"Teams building open pandemic ventilators tend to be poorly funded and geographically distributed. VentMon's connectivity and overall cost address these two challenges by enabling team members on different continents to view waveforms ***(see Figure 15)*** *in real time and communicate the necessary adjustments to the ventilator device under test. While reliance on the internet is a strength for a distributed and virtually connected engineering team, it would be an addressable disadvantage in a field hospital.*

Design files

- In the table it says "Open source license [check these]." This is confusing. Please verify the correct license is listed
    - *Line 175 - FIXED*
    - *Licenses VERIFIED*

Validation and characterization

- The manuscript would benefit from some quantitative measures of sensitivity and more information about the common operating ranges of the device. For example, these descriptions for a VentMon made with a particular a flow sensor, can give the readers an idea of what is achievable for a given sensor selection. Even if measurements are differential, it is still possible to determine the sensitivity and the ability of the device to reproduce measured data. On page 22, the authors write, "The reliability of the data is inherently tied to the accuracy and precision of the device producing data for VentDisplay." Please be more specific and quantitative about the "reliability of the data".

- On page 22, the authors write, "VentMon is unique in this regard as the flow, differential pressure, and oxygen sensors used in the design require no calibration. After independent testing each component the VentMon team found that the flow and oxygen measurements are suitable for accurately measuring FiO2 mixing in mechanical ventilation." Please define "suitable for accurately measuring" in a quantitative fashion."

In response to these two related comments, we have rewritten the paragraphs below, and we thank the reviewer for suggesting these excellent improvements:

"This VentDisplay software has been shown to be valuable, although it is dependent on accurate software decisions about the beginning and the ending of a breath, which can be subtle in some situations. The reliability of the data is inherently tied to the accuracy and precision of the device producing data for VentDisplay, which may or may not be a VentMon.

"The flow and differential pressure sensors used in the VentMon require no calibration. A VentMon equipped with the Sensirion SFM3200-AW was tested with a calibrated 500ml syringe by integrating flow to obtain volume and found to reproduce volume and therefore flow more accurately than 2%. This commercial flow sensor measures a maximum flow of 250 slm (standard liters per minute). This range is almost impossible to exceed for a human being (by design). Nonetheless, because we sometimes had to use a neonatal flow sensor with a limit of 80 slm, our software detects this limit and publishes a PIRDS error event when the sensor "clips", which extends to the adult flow sensors as well.

"The oxygen sensor spec sheet claims to be within 1% of FiO_2. Since clinical practice normally prescribes FiO_2 in steps of 10%, this seems accurate enough for both clinical use and the current intended use of testing ventilator equipment. The differential pressure sensors have a resolution of 0.5 cmH_2O.