Validation of a novel fibreoptic sensor integrated in oxygen delivery devices as a respiratory rate monitor

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Measurement of respiratory rate has been integrated into multiple early warning scoring systems (EWS). However, outside critical care areas this usually involves manual counting of respiration (MC) or estimation via electrocardiogram.

We have developed a device which measures humidity in exhaled air and can do so on a breath to breath basis.[1] It uses optical fibre technology that can be easily integrated into oxygen delivery devices such as masks and nasal cannulae.

Our objective was to the performance of our device as a respiratory rate monitor using three different types of oxygen delivery devices and comparing it against the current gold standard (CO2 analysis) and manual counting.

Methods:

This was a single centre observational study. Approval was gained from the University of Nottingham research and ethics committee.

Volunteers were randomised to the order of use of each of the three devices being studied, and three respiratory rates (RR), ie., CO2 mask(CM), trauma mask (TM) and nasal cannulae (NC) and rates of 5, 12 and 30 breaths per minute. The optic fibres were protected by sealing the tip in a blunted needle. This was integrated into CM, TM and NC.

Participants were assisted to maintain the correct respiratory rate using a smartphone based application (Paced breathing). They were allowed time to acclimatize using each oxygen delivery device at the selected respiratory rates before commencement of the data collection. Data were collected for a period of two minutes for each of the devices at each respiratory rate. RR were measured using MC, expired CO2(eCO2) and our device.

In the second part of the study, participants were encouraged to maintain tidal volumes <100 mL for one minute through a tight-fitting mask. The volumes were measured through a variable flow orifice built into and used for measurement of tidal volumes in an anaesthetic machine (Aestiva 5).

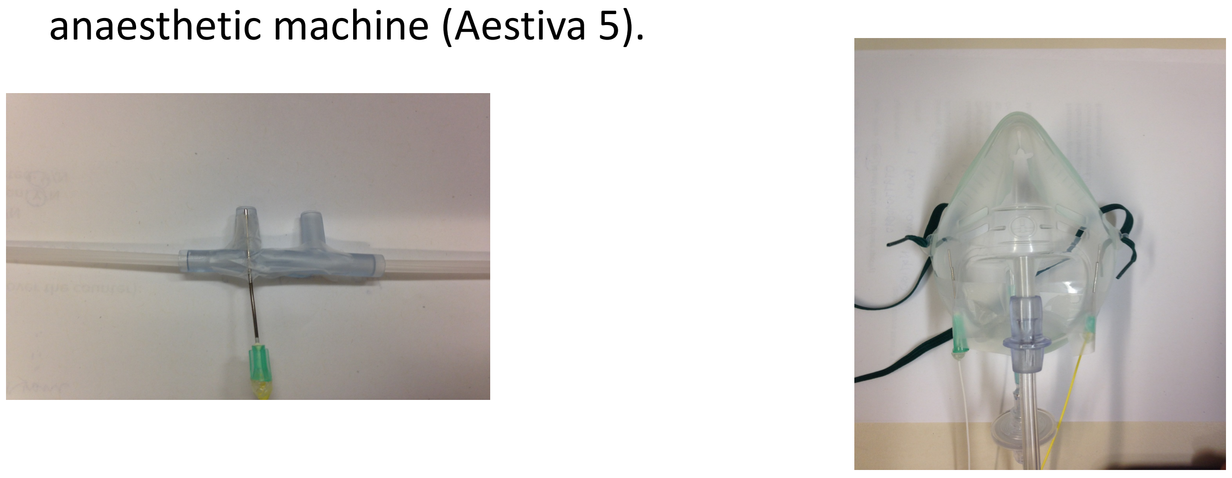

Figure 1: Measuring fibre integrated in nasal cannulae and a CO2 mask

Results:

We collected data from all 20 participants. There was one failure with data collection with the first participant. This was due to a low sampling rate and was solved by amending the analysing software. Below are some images from the data analysis from our device.

The device demonstrated a 100% correlation with the accepted gold standard methods, ie., MC and eCO2. We noted several discrepancies between TIP and MC and TIP and eCO2, especially at the extremes of respiratory rates we were measuring.

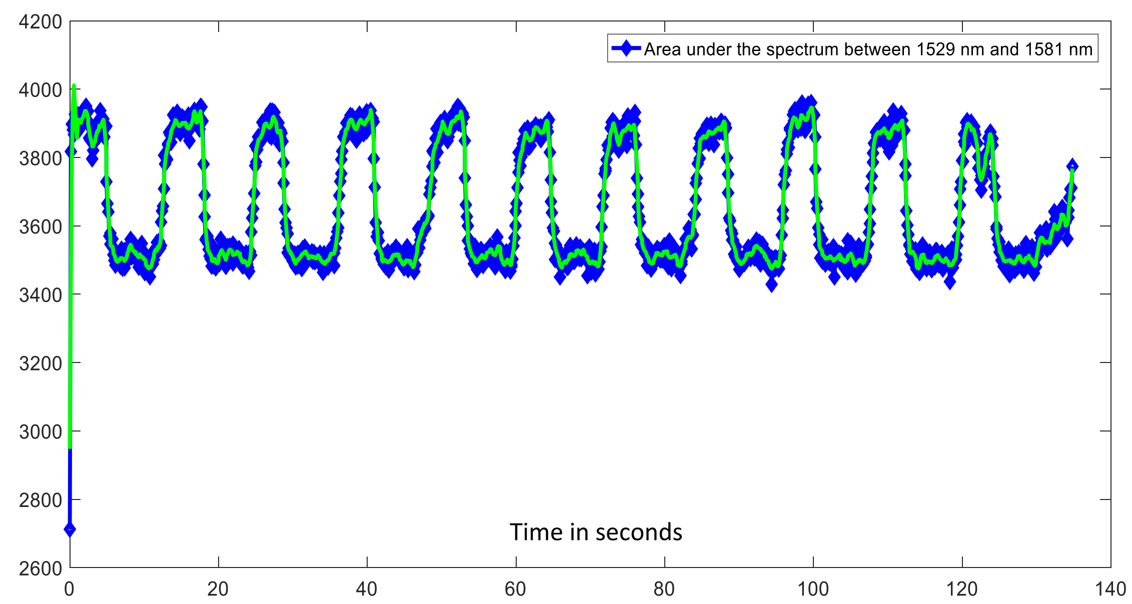

Figure 2 a

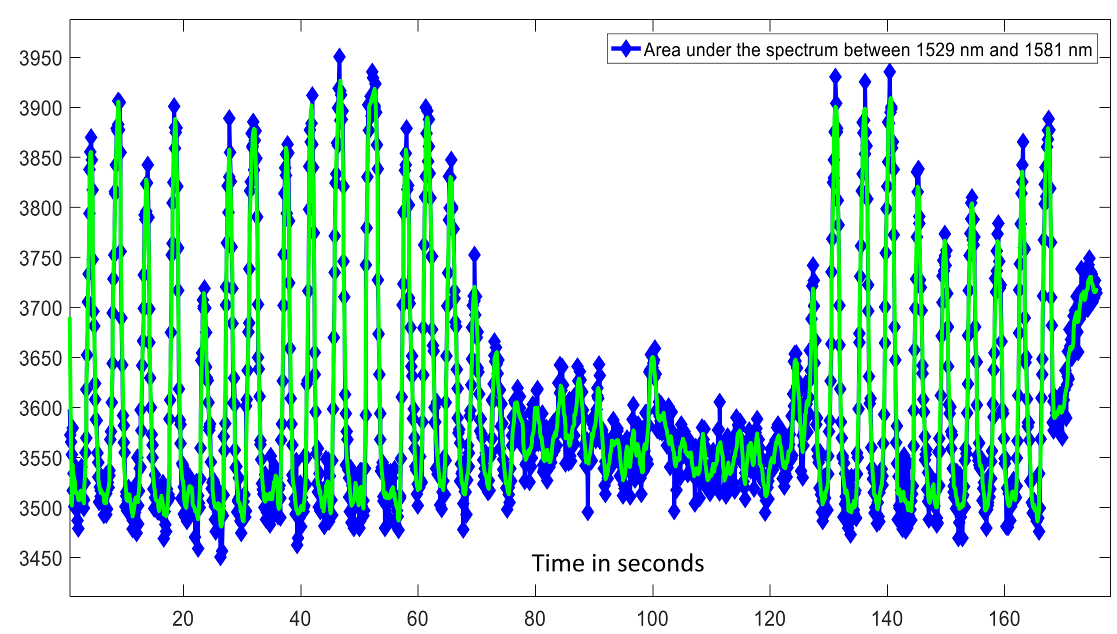

Figure 2 b

Figure 2: Y axis = area under curve of the reflection spectrum.
a. Analysed trace of the fibre-optic sensor when used in nasal cannulae at a RR of 5 bpm. b. Trace demonstrating period of low tidal volume with normal breathing on either side.

Discussion:

We have demonstrated function of our device and its ability to provide an accurate and repeatable measurement when compared to accepted standards. The issues with the software were analysed early on and changes made. We believe the issues noted with TIP measurements at extremes of respiratory rate are a reflection of their unreliability in this aspect of their use.

Future work:

We are currently in the process of writing this work for a future grant application to develop our software to allow breath by breath analysis and carry out a study in a clinical setting.

References:

1. **Characterization and use of a fiber optic sensor based on PAH/SiO 2 film for humidity sensing in ventilator care equipment.** Hernandez, F. U., Morgan, S. P., et al. (2016). IEEE Transactions on Biomedical Engineering, 63(9), 1985-1992.