



Early Prediction of COVID-19 Patient Deterioration Utilizing Non-Invasive Respiratory Volume Monitoring

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Introduction

- Viral pneumonias, such as COVID-19, can result in respiratory compromise leading to death.
- Hyperventilation is an early sign of viral pneumonia (in advance of hypoxia, and more specific than respiratory rate) and can provide a leading indicator to identify patients at-risk of respiratory compromise.
- Hospitals have used technologies such as pulse oximetry and capnography to track respiratory status; however, these methods provide indirect measurements of ventilation with delayed responses and are plagued by multiple false alarms.
- We have directly monitored minute ventilation (MV) using a respiratory volume monitor (RVM) in patients with COVID-19 on the hospital floor and the ICU to track disease progression and inform decisions on treatment. Here we describe two illustrative patients.

Methods

- Patients were monitored after admission to the hospital floor or ICU. An RVM (ExSpiron 1Xi, Respiratory Motion Inc, Watertown MA) was used to measure MV, tidal volume (TV) and respiratory rate (RR) via an L-shaped electrode padset placed on the thorax (Fig 1).
- MV was reported as a percent of predicted MV (MV_{PRED}) for each patient based on height, weight and gender. COVID-19 diagnoses were confirmed with real time PCR tests.



Figure 1. Non-invasive RVM that provides continuous, real-time measurements of MV, TV, and RR. Figure shows standard PadSet placement: sternal notch, xiphoid, and right mid-axillary line at the level of the xiphoid.

Conclusions

- We have noted that monitoring minute ventilation has contributed to our overall understanding of COVID-19 pneumonia progression as specifically demonstrated in the cases presented. The RVM provided a leading indicator of adequate ventilation in one case and of respiratory failure in the other.
- The patient on the hospital floor was able to maintain adequate oxygenation with slightly elevated minute ventilation and recovered quickly. However, the ICU patient had significantly and persistently elevated minute ventilation, indicative of continued deterioration despite escalating interventions, ultimately resulting in intractable hypoxemia, intubation and death.
- Based on these and other preliminary data, patients with $MV >300\%$ may be considered for escalation of care and earlier intubation.
- The RVM has the potential to identify patients at risk for deterioration and drive timely management decisions to improve the care of COVID patients and optimize resource allocation.

Case Study 1

- A 58 year old male was hospitalized with cough, fever, diarrhea, and hypoxemia.
- The patient was initially placed on oxygen via nasal cannula and later non-rebreather mask.
- The patient continued to deteriorate and was transferred to the ICU, where the RVM reported MV values over 300% of MV_{PRED} with RR of 40 breaths per min. The patient was placed on BiPAP but MV remained elevated (200 to $>300\%$ of MV_{PRED}) without improvement (Fig 2).
- The decision to intubate was made after patient desaturated despite BiPAP and 100% FiO₂. Further deterioration over the next six days lead to cardiac arrest and death.

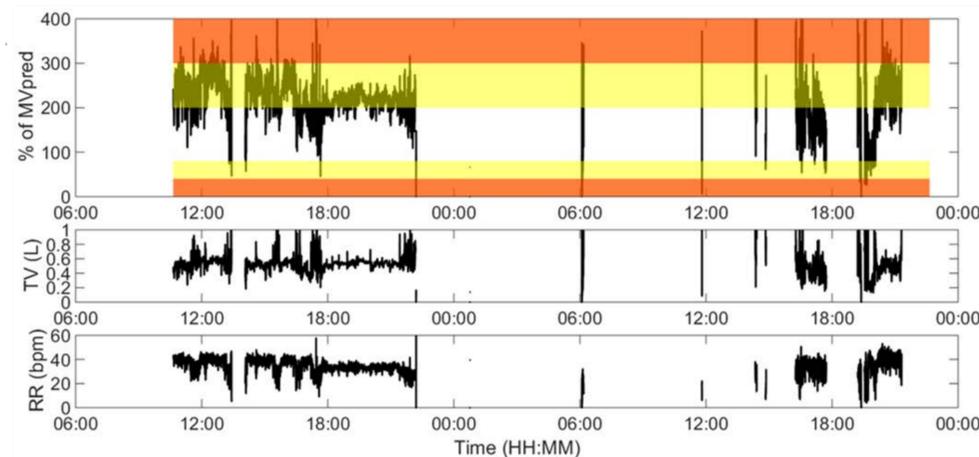


Figure 2. A 58 year old male was monitored with the RVM during non-invasive ventilation with BiPAP. MV (200%-300%) remained elevated, often over $>300\%$ MV_{PRED} , throughout the monitoring period, despite escalating interventions, coinciding with patient deterioration.

Case Study 2

- A 65 year old male was admitted for monitoring on the hospital floor with COVID-19 symptoms including cough, fever, and chills. On admission, MV measurements were $<200\%$ MV_{PRED} .
- Chest X-rays revealed hazy infiltration in the periphery of the lungs. However, the patient maintained adequate oxygenation throughout his hospital stay ($>94\%$) while breathing at a somewhat elevated minute ventilation, but at no point exceeding 200% of MV_{PRED} .
- Although RR rose to high 20s at times, TV remained within normal range, resulting in sustainable ventilation and work of breathing (Fig 3).
- The patient was initially placed on 2L nasal cannula, but was quickly titrated down to room air and discharged after being afebrile for 4 days.

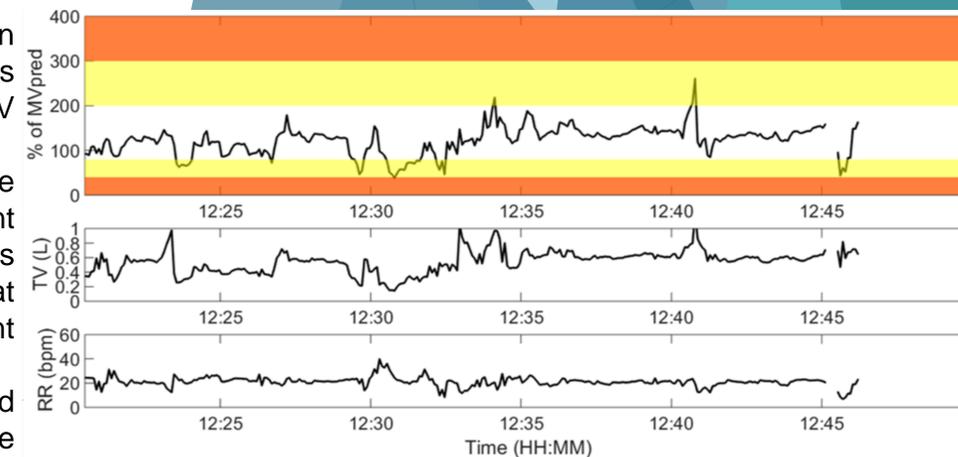


Figure 3. Excerpt of MV, TV and RR in 65 year old male monitored with RVM during hospital floor stay. Although RR increased above 20 bpm at times, MV remained below 200% of MV_{PRED} .