Non-Invasive Respiratory Volume Monitoring Provides Quantitative Measurements that Provide a Better Assessment of Ventilatory Status than Capnography-Generated Respiratory Rates

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Introduction: Clinicians often face a dilemma, when identifying appropriate patient monitoring: more accurate and more reliable measurements can be associated with a higher cost. Sometimes the cost is material such as CT versus x-ray and at other times it results in increased patient discomfort or risk of infection (invasive BP vs NIBP). Respiratory monitoring of non-intubated patients is particularly challenging, because until recently, any direct measurements of true respiratory effort involved the use of a tight-fitting mask attached to either a spirometer or pneumotachometer, making this method clinically impractical. Instead, clinicians often rely on secondary indicators of respiratory sufficiency, such as pulse oximetry (SpO_2) and capnography ($EtCO_2$). Unfortunately, relevant changes in SpO_2 are easily masked by the use of supplemental oxygen and $EtCO_2$ measurements in non-intubated patients are frequently unreliable to the point where clinicians resort to using only the respiratory rate (RR) measurements from the capnograph. A recently developed non-invasive respiratory volume monitor (RVM), which continuously measures minute ventilation (MV), tidal volume (TV) and respiratory rate (RR), addresses majority of these concerns. RVM also provides a new way to accurately assess the ability of $EtCO_2$-generated RR to adequately quantify respiratory status in non-intubated patients.

Methods: Continuous RVM and capnography data were collected from 50 subjects (age:46 ±14 yrs; BMI:27.6 ±6.1 kg/m^2) using an impedance based RVM (ExSpiron, Respiratory Motion, Inc., Waltham, MA), and a capnograph (Capnostream 20, Covidien, Mansfield, MA) using a sampling oral/nasal cannula (Smart Capnoline Plus). Each subject performed six 2.5-min breathing trials at various RRs. The correlations between $EtCO_2$ measurements (low: <35 mmHg, normal: 35-45 mmHg, high: >35 mmHg), capnography-based RR (low: <6 b/min, adequate: >=6 b/min), and RVM-based MV (low: <2L/min, adequate: >=2 L/min) were evaluated.

Results: A direct comparison of MV and $EtCO_2$ measurements revealed that in only 24.6% of the 9324 analyzed epochs adequate MV coincided with normal $EtCO_2$. 68.7% of the time adequate MV coincided with a low $EtCO_2$ and, 100% of low MV measurements corresponded to either normal or low $EtCO_2$ (Fig 1A). Similarly poor correlation was present between the capnorgaph's RR and $EtCO_2$ measurements: normal $EtCO_2$ coincided with adequate RR just 24.9% of the time and none of the low RR measurements were indicative of a high $EtCO_2$ (Fig 1B). When using RR as a proxy for MV it was also noted that low MV is observed at a wide range of RRs, with only 15.5% of all low MV events captured by a low $EtCO_2$-based RR (Fig 1C).

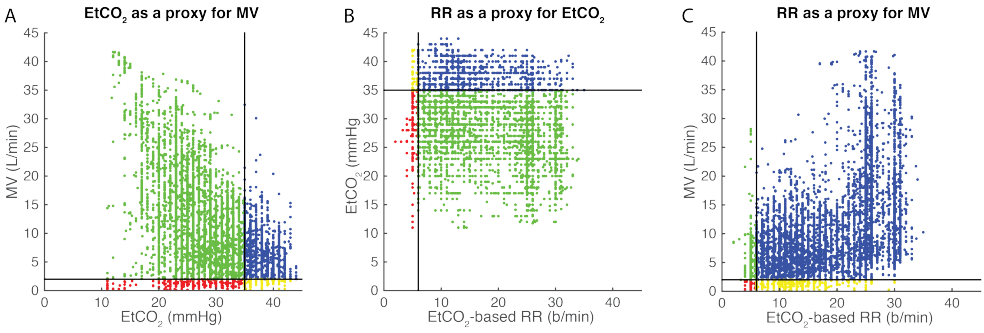

Figure 1: Analysis of the collected measurements (9324) reveals poor correlations between (A) EtCO2 and MV (B) RR and EtCO2 and (C) RR and MV, despite RR being derived from $EtCO_2$ and MV being a function of RR (MV=TVxRR).

Conclusions: This study confirmed that (a) EtCO2 is an inadequate proxy for MV in non-intubated patients, (b) EtCO2-based RR is a poor proxy for EtCO2, and even more concerning, (c) EtCO2-based RR is an even worse proxy for MV. Ultimately, the data demonstrated that relying on capnography to capture the volatile nature of respiratory status in non-intubated patient's is highly inadequate and one must carefully weigh the cost-savings against the increase in patient risk and the likelihood of incurring extra cost due to preventable respiratory complications.