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 (SpO₂) and capnography (EtCO₂). Unfortunately, relevant changes in SpO₂ are easily masked by the use of supplemental oxygen and EtCO₂ 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 EtCO₂-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/m²) 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 EtCO₂ 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 EtCO₂ measurements revealed that in only 24.6% of the 9324 analyzed epochs adequate MV coincided with normal EtCO₂. 68.7% of the time adequate MV coincided with a low EtCO₂ and, 100% of low MV measurements corresponded to either normal or low EtCO₂ (Fig 1A). Similarly poor correlation was present between the capnograph’s RR and EtCO₂ measurements: normal EtCO₂ coincided with adequate RR just 24.9% of the time and none of the low RR measurements were indicative of a high EtCO₂ (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 EtCO₂-based RR (Fig 1C).
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.

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 EtCO2 and MV being a function of RR (MV=TV×RR).