Introduction

When identifying appropriate patient monitoring, clinicians are often faced with accuracy-cost trade-off decisions. A CT scan may be more accurate than a standard X-ray, but it comes at a higher material cost. Invasive BP measurements are more accurate than NIBP, but the associated cost may include increased patient discomfort or risk of infection. 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 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 many 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. This study demonstrates that the RVM’s quantitative measurements provide a better assessment of ventilatory status than capnography-generated respiratory rates.

Methods

Equipment and Population: After obtaining written informed consent continuous respiratory data were recorded from an RVM (ExSpiron, Respiratory Motion, Waltham, MA) via an electrode PadSet placed on the thorax (Figure 1) simultaneously with capnography data (Capnostream 20, Covidien, Mansfield, MA) using a sampling oral/nasal cannula (Smart Capoline Plus) from 50 subjects (age: 46 ±14 yrs; BMI: 27.6 ±6.1 kg/m²).

Experimental Design: Each subject performed six 2.5-min trials of breathing at various RRs including “normal” breathing and “slow” and “fast” breathing at 2 pre-defined RRs (5 and 25 breaths/min, respectively).

Metrics: For each subject, we calculated the ratio between the observed changes in MV (e.g. when transitioning from slow to fast breathing) and the corresponding changes in EtCO2 measurements. We used this ratio as a proxy for the sensitivity of the capnography monitor to reflect changes in MV. 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: <2 L/min, adequate: >=2 L/min) were also evaluated.

Statistics: Pearson correlations were used to compare the RR measurements derived from the RVM and the capnograph during periods of steady breathing. Multi-factor ANOVA was used to evaluate differences in sensitivity across sampling modalities and paired t-tests were used to compare the rate of change of RR, MV and EtCO2 measurements between the two devices as breathing patterns changed.

Results

During steady breathing, the correlation between the RR reported by the RVM and the capnograph was 0.98 ±0.05 (mean±SD) and the average difference in RR measurements was 0.7±0.4 breaths/min. During transitions between breathing patterns, the RVM-based RR reflected the change over 32.1 ±1.2 sec, while the capnography-based RR was slower to respond (63.3 ±4.8 sec, significantly greater than the RVM, p<0.001; Figure 2). The differences in the rate of change of MV and EtCO2 were even more pronounced. The RVM MV reflected the change in respiratory pattern in 31 ±1 sec on average while the capnograph was notably slower, often failing to reach a new asymptote over the course of 2.5 minutes (150 sec).

Conclusions

- EtCO2 measurements lack the fidelity to adequately capture rapid changes in ventilation.
- EtCO2 is an inadequate proxy for MV in non-intubated patients.
- EtCO2-based RR is a poor proxy for EtCO2 in non-intubated patients.
- Relying on capnography to capture the volatile nature of respiratory status in non-intubated patients is highly inadequate
- RVM is potentially a better tool to measure adequacy of ventilation in non-intubated patients since it provides a direct measure of MV
- Clinicians must carefully weigh the cost-savings against the increase in patient risk and the likelihood of incurring extra cost due to preventable respiratory complications.

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