The Evaluation of a Non-Invasive Respiratory Volume Monitor in Surgical Patients Undergoing Elective Surgery under General Anesthesia

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Introduction

Continuous respiratory monitoring is important for predicting and identifying potentially life-threatening respiratory compromise, performing clinically-appropriate interventions, and monitoring patient recovery. Currently, continuous respiratory monitoring is often tied to mechanical ventilation, an essential support therapy to maintain adequate gas exchange during general anesthesia, and is no longer available once the patient is extubated. During the recovery phase, respiratory depression and subsequent adverse outcomes can arise due to residual anesthetics and/or opioid administration. Until recently there was no technology that non-invasively measured the adequacy of ventilation in non-intubated patients. A novel, non-invasive Respiratory Volume Monitor (RVM) has been developed that provides continuous, real-time, accurate measurements of minute ventilation (MV), tidal volume (TV), and respiratory rate (RR). This study demonstrates that RVM’s non-invasive measurements of MV, TV and RR closely match the ventilator measurements during general anesthesia in elective orthopedic patients.

Methods

After obtaining written informed consent digital respiratory traces were collected from 10 patients (six female, mean age of 62.1 ± 8.2 years; mean BMI of 28.9 ± 8.9) undergoing elective joint replacement surgery (four knee replacements and six hip replacements) with general anesthesia from a bio-impedance based RVM system (ExSpiron, Respiratory Motion, Waltham, MA) via an electrode PadSet placed on the patients’ thorax (Figure 1). After synchronization digital respiratory traces and measurement data (MV, TV and RR) were gathered continuously from the RVM as well as from the anesthesia ventilator (Draeger Apollo, Andover, MA) during the entire operative procedure. Operative procedure times varied between 65 and 420 minutes (95%/90/102 minutes, mean ± SD) for the patient’s studied. RVM’s measurements were compared to the ventilator measurements (using standard methods\(^1\)) and measurement bias, precision and accuracy were calculated. Comparisons between the digital traces were also computed during corresponding trace segments.

Results

Analysis showed a close match between the RVM measurements of MV, TV and RR and the ventilator (Figure 2). Measurement error analysis of data is shown in Bland-Altman plots of MV, TV and RR error (Figure 3). Each data point (black) corresponds to a single measurement. The blue “+” signs show subjects’ average error for each parameter. The absissa was computed as the average between the two devices, whereas the y-axis is the difference between the ventilator and the RVM. The average MV difference between the RV and ventilator is -0.10 L/min with a measurement bias of -1.3%, precision of 6.6%, and accuracy of 9.0%. The average TV difference was 0.04 ml with a bias of 0.4%, precision of 7.3%, and accuracy of 9.1%. The average RR difference was -0.22 breaths/minute with a bias of -8.1%, precision of 3.7% and accuracy of 4.1%. Examples of the correlations between the continuous digital traces from the RVM and the ventilator were compared at various points during surgery and had correlations >0.90 throughout. Example trace pairs are shown in Figure 4.

Conclusions

- Data demonstrate good correlation between RVM and ventilator respiratory traces.
- The RVM measurements of MV and TV have a relative error of <10% (9.0% and 9.5%) respectively while RR had a relative error of <5% (4.1%) when compared to the ventilator.
- This study is in line with previous results comparing the accuracy of the RVM to spirometry.
- These results provide the foundation for RVM use in the assessment of respiratory status in non-intubated patients.
- The RVM allows providers to have real-time non-invasive measurements of MV, TV and RR that can lead to therapeutic interventions, improve patient safety and decrease healthcare costs.