Comparison of Tidal Breathing Flow-Volume Loops Generated by a Respiratory Volume Monitor and Spirometry

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Introduction: Flow-volume loops (FVLs) are used to diagnose and monitor the progression and treatment of lung disorders such as COPD and asthma. The gold standard for generating FVLs is a spirometry-based forced vital capacity test, which requires the use of a mouthpiece or facemask and patient cooperation to generate maximum effort breaths. These tests cannot be performed by young children and adults unable to follow instructions. For these patients, the use of tidal breathing flow-volume loops (TBFVLs) has been proposed but has not been widely adopted due to lack of a reliable, non-invasive, technological solution. An impedance-based respiratory volume monitor (RVM) non-invasively measures minute ventilation and can be used to generate TBFVLs. The objectives of this study were: 1) to use a spirometer to evaluate TBFVLs measured by the RVM in healthy volunteers and 2) to monitor TBFVLs in post-operative patients using only the RVM over an extended period of time.

Methods: As part of an IRB approved study, 20 healthy adult volunteers were simultaneously monitored with a RVM (ExSpiron 1Xi, Respiratory Motion Inc, Waltham, MA) and a pneumotachometer (SpiroAir-LT, Morgan Scientific, Haverhill, MA) while breathing at rest for 10 minutes. Another 20 patients recovering from abdominal surgery were monitored with only the RVM for up to 48 hours on a hospital floor. TBFVLs and metrics were recorded for both devices including: respiratory rate (RR), tidal volume (TV), inspiratory time (tI), expiratory time (tE), inspiratory and expiratory ratio (tI/tE), duty cycle (tI/tTot) and inspiratory and expiratory flow ratio at 50% tidal volume (IE50). Bland Altman accuracy of TBFVL metrics were calculated for volunteers using the pneumotachometer as the gold standard. TBFVLs were visualized over time for post-operative patients.

Results: Bland Altman analysis showed that the differences between the RVM and pneumotachometer was small and clinically irrelevant for TV and RR, with a root mean square error (RMSE) of 9.9% and 1.5%, respectively. The RMSE for tI and tE measured for each breath were 11.8% and 10.9%, respectively. The RMSE for ratios tI/tE, tI/tTot and IE50 were 15.3%, 10.8% and 17.0% respectively. In order to visually detect changes in TBFVLs over extended monitoring periods from post-operative patients, breath by breath TBFVLs (Figure 1A) were also visualized as 3D plots over time (Figure 1B). Sample traces of breath by breath volume, flow, peak tidal expiratory flow, and volume at peak tidal expiratory flow were also plotted against time (Figure 1C).

Conclusions: The RVM can generate TBFVLs that are similar in morphology compared to spirometry without the need for patient cooperation or inconvenient instrumentation. Therefore, the RVM can be used to non-invasively monitor TBFVLs and provide clinically relevant pulmonary metrics for extended durations. The FVLs and metrics generated by the

RVM can potentially be used to detect anomalies in breathing and diagnose patients, either at the bedside or in the pulmonary function test laboratory.

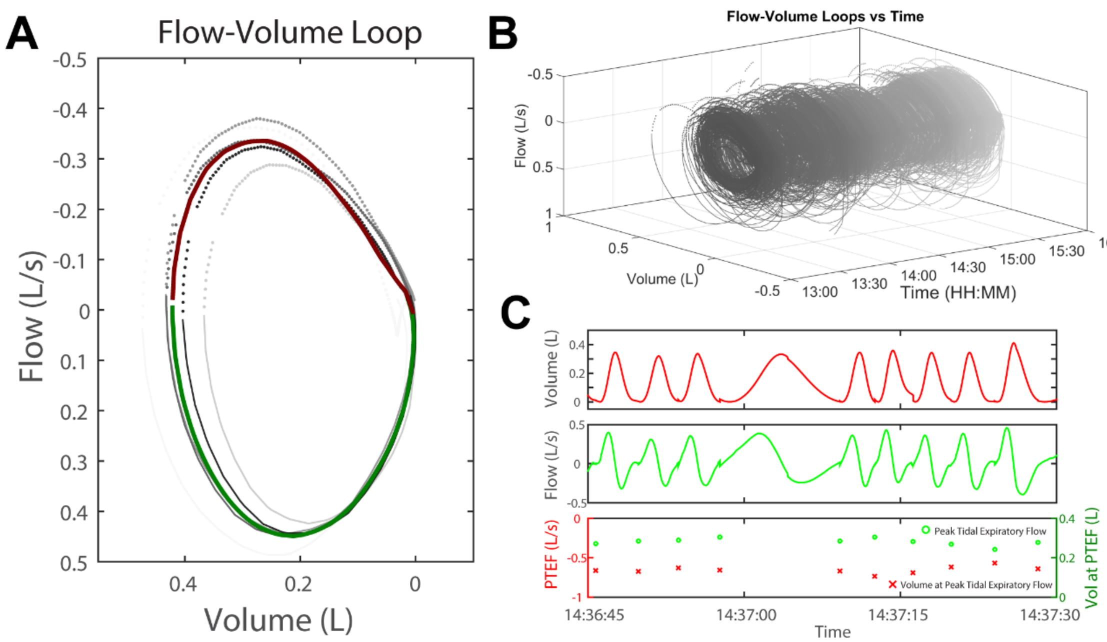

Figure 1: A) Sample flow-volume loop for four consecutive tidal breaths (grey), averaged together for inspiration (green) and expiration (red). **B)** Flow-volume loops plotted vs time in 3D. **C)** Sample volume, flow, peak tidal expiratory flow (PTEF), and volume at PTEF plotted vs time.