Obstructive sleep apnea (OSA) is both common and grossly underdiagnosed medical condition that affects all age groups and is estimated to have up to a 26% prevalence in the general population. Surgical patients with moderate-to-severe OSA are considered at risk for increased post-operative respiratory complications, which can lead to increased morbidity and mortality. Of surgical patients, the obese population in particular has a high prevalence of OSA and is considered at high risk for post-operative respiratory compromise. As such, it is important to develop peri-operative care protocols to assist in the prediction of post-operative recovery outcomes. Here we use a non-invasive respiratory volume monitor (RVM) to quantitatively evaluate respiratory function in non-intubated obese surgical patients. By monitoring, in real-time, tidal ventilation (MV), tidal volume (TV) and respiratory rate (RR), the healthcare team can risk-stratify patients in the post-anesthesia care unit (PACU) for unrecognized OSA.1 In this study, we extend the duration of monitoring with the RVM after PACU discharge to include the first post-operative night (PON1) on the general hospital floor (GHF). The goals of the study were to quantify the incidence of Low MV (LMV), a metric for identifying post-operative respiratory depression, and evaluate the effect of Low MV (LMV) on the general hospital floor (GHF). The goals of the study were to quantify the incidence of Low MV (LMV), a metric for identifying post-operative respiratory depression, and determine whether LMV alone is an adequate measure to identify LMV episodes in obese post-operative patients.

**Methods**

**Equipment and Population:** This observational study was conducted in the PACU and GHF at Tufts Medical Center (Boston, MA). Institutional Review Board (IRB #8) approval was obtained for the monitoring of respiratory function in obese (BMI > 35kg/m²) patients, aged at least 18 years, undergoing elective bariatric or general surgical procedures. Following written informed consent, patients were monitored continuously in the PACU and during the PON1 with an impedance-based RVM (ExSpiron, Respiratory Motion, Inc., Waltham, MA). Digital respiratory traces and MV, TV, and RR measurements were collected via a three-electrode PadSet placed on the thorax (Figure 1).

**Results**

Ten post-surgical patients (median age 40 (range 20 – 65); median BMI 44.0 (range 35.9 – 59.6) kg/m²) were monitored in the PACU and on the GHF for an average of 9.2 ± 1.9 hrs (3.0 ± 0.4 in PACU and 6.1 ± 2.1 hrs on GHF). Of the cohort had a STOP-Bang score ≥ 3, indicating a high probability for moderate-to-severe OSA. Using continuous PACU and GHF RVM recordings for all 10 patients, 32 LMV episodes were identified: 3 patients with 0 episodes, 6 patients with 1 – 6 episodes and one patient with 12 episodes (Figure 2). The average number of LMV episodes was 3.2 ±1.1 per patient, with each episode having an average duration of 181.6 ±68.6 sec. 1.6 ± 0.7 LMV episodes were monitored in the PACU and on the GHF for an average of 9.2 ± 1.9 hrs (3.0 ± 0.4 in PACU and 6.1 ± 2.1 hrs on GHF).

BMI is calculated by dividing body mass (in kg) by the square of body height (in m²). LMV was defined as measured MV < 40 % of MVPRED. Results of previous studies suggest that patients at high risk for OSA had an average of 3 LMV episodes per patient (0.34 ±0.11 episodes per hour). These were split between the PACU (1.6 ±0.7 episodes per patient, 0.51 ±0.24 per hour) and the GHF (1.0 ±0.7 episodes per patient, 0.24 ±0.09 episodes per hour). When analyzing only the 7 of 10 patients with recorded LMV episodes the average number of LMV periods was 4.6 ± 1.3 episodes per patient (0.48 ±0.12 episodes per hour). These were split between the PACU (3.2 ± 1.1 episodes per patient, 1.02 ± 0.34 per hour) and the GHF (3.2 ± 1.0 episodes per patient, 0.48 ± 0.10 episodes per hour). There was no statistically significant difference in the RR measurement between AMV and LMV episodes (19.2 ± 1.3 bpm vs 15.5 ± 1.2 bpm, p < 0.01) and no LMV episodes were due to a sustained low RR (<6 bpm). Conversely, TV significantly decreased during LMV episodes from 119.8 ±57.6 ml to 126.0±6.0 ml (p = 0.001, Figure 3).

Despite a STOP-Bang score ≥ 3 in 57% of the surgical cohort, low minute volume periods only occurred on average 3.2±1.1 times per patient during the observational period at a mean duration of 181.6±68.6 seconds per episode. LMV episodes were characterized by a significant decrease in TV, but not RR. This is similar to recently published data from procedural sedation, suggesting that RR monitoring alone is insufficient to detect inadequate MV in postoperative patients. Future correlation of postoperative opioid and sedative administration with respiratory monitoring to identify patients at risk in a larger cohort is warranted. Accurate quantitative respiratory volume monitoring in non-intubated patients allows real-time, point-of-care assessment as well as observation MV, TV and RR trends, facilitating timely interventions and improved patient care.

**Discussion**

**Conclusions**

1. Patients at high risk for OSA had an average of 3 LMV episodes per patient

2. The average duration of LMV was 3 minutes

3. Patients had no LMV and would have registered no alarm

4. Patients would have registered 1-6 alarms

5. Patients had 1 episode of LMV that would have triggered an alarm

6. LMV episodes were characterized by a significant decrease in TV

7. RVM may be particularly useful perioperatively in high risk, obese surgical patients, where moderate-to-severe OSA is of greater prevalence.

**References**


2. Schmieder WA. JASA 2014

**Figure 1.** A non-invasive Respiratory Volume Monitor (RVM, ExSpiron, Respiratory Motion, Inc.) that provides continuous, real-time, non-invasive measurements of MV, TV, and RR. Figure shows standard electrode placement on an obese patient (BMI > 35 kg/m²). One electrode is placed at the sternal notch, another on the xiphoid and the third is placed in the right mid-axillary line at the level of the xiphoid. (Consent obtained for photograph).

**Figure 2.** Low MV episodes across the cohort. (A) Probability density function of the likelihood (y-axis) that a Low MV period of a given length (x-axis) would occur on that more than the average patient. The average length lasted more than 2 minutes. (B) Distribution of LMV episodes across all 10 patients in the PACU (grey bars) and combined across the PACU & GHF (dark blue). Note that in patients who/o any LMV episodes the average episode duration was 1.3 ± 0.51 and greater than the average. The average number of LMV periods was 4.6 ± 1.3 episodes per patient (0.34 ±0.11 episodes per hour). These were split between the PACU (1.6 ±0.7 episodes per patient, 0.51 ±0.24 per hour) and the GHF (1.0 ±0.7 episodes per patient, 0.24 ±0.09 episodes per hour). When analyzing only the 7 of 10 patients with recorded LMV episodes the average number of LMV periods was 4.6 ± 1.3 episodes per patient (0.48 ±0.12 episodes per hour). These were split between the PACU (3.2 ± 1.1 episodes per patient, 1.02 ± 0.34 per hour) and the GHF (3.2 ± 1.0 episodes per patient, 0.48 ± 0.10 episodes per hour).

**Figure 3.** Changes in RVM metrics during “LMV” episodes. Changes in RVM metrics from periods of Adequate MV (blue) to periods of “LMV” (red). Panels (A), (B) and (C) show the observed metrics during the 2 types of periods. Note that in producing these plots we first calculated patient average MV, TV, and RR and then averaged these values across patients to get the height of each bar and computed the SEM across patients for the error bars. Since patients had no LMV episodes, the red bars are based on the data from 7 patients and the SEMs and statistics are computed accordingly.

****signifies p < 0.001, which shows high significance

N.S. signifies p > 0.05, which shows no significance

Whiskers represent SEM.