Assessing the Effects of Duration of Apnea on Adequacy of Ventilation across a Broad Cohort of Surgical Patients in the Post-Operative Environment

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Introduction

- Maintaining respiratory sufficiency is a vital component of postoperative care, yet clinicians often rely on subjective clinical assessments or secondary indicators to make decisions regarding opioid administration, non-invasive ventilation, discharge, or triage to higher acuity areas.
- Patients with apneic episodes are often considered to have “respiratory insufficiency” regardless of whether these apneic episodes impact overall respiratory status or are compensated by large recovery breaths.
- We used a non-invasive respiratory volume monitor (RVM) to quantitate patient minute ventilation (MV), an objective measure of respiratory status, to assess adequacy of ventilation in patients experiencing apnea in the PACU and on the general floor.

Methods

- IRB approved observational study: 216 patients following elective abdominal surgery at Cleveland Clinic.
- The non-invasive Respiratory Volume Monitor (RVM, ExSpirom, Respiratory Motion, Inc., Waltham, MA) provides accurate respiratory metrics when tested against spirometry and ventilator measurements, with 90% accuracy for MV and TV, and 98% accuracy for RR (1,2).
- Minute ventilation (MV), tidal volume (TV), and respiratory rate (RR) were continuously measured by the RVM for up to 48 hours post-op.
- Predicted MV (MV_{PRED}) was calculated for each patient based on body surface area (3). A Low MV event (LMVe) was defined as $MV < 40\%$ of MV_{PRED} sustained for at least 2 minutes (4).
- Apnea was defined as a respiratory pause > 10 seconds.
- For each apnea, we calculated the patient’s corresponding MV over the 30 sec, 60 sec, 90 sec, and 120 sec windows following the start of the apnea.

Figure 1. Non-invasive RVM that provides continuous, real-time measurements of MV, TV, and RR. Figure shows standard PadSet placement: sternal notch, xiphoid, and right mid-axillary line at the level of the xiphoid.

Results

- 216 patients (110 males, BMI: 26.7 (15.1-41.2) kg/m²) were enrolled and monitored for 42.0 ± 0.9 hours.
- We recorded a total of 49,985 apneas ranging in length from 10-117 seconds (Figure 2). Apnea greater than 10 seconds was observed in 99% of patients, suggesting that apnea per se is a poor indicator of respiratory insufficiency.
- The average MV was 73% ± 2.4% of MV_{PRED} , as patients were often sleeping or mildly sedated.
- We assessed the effects of each apnea on the temporally associated MV (Figure 3). While apneas ranging in length from 10-18 seconds decrease instantaneous MV by as much as 30%, their effect over the course of 1-minute is less than 10%.
- On a 2-minute time scale, even 60-second long apneas lead to Low MV just 20% of the time (Figure 4).

Figure 2. Distribution of apneas across a surgical population. Apneas greater than 10 seconds were recorded in 99% (214 out of 216) patients in the post-operative period and 92% of the recorded apneas were less than 20 seconds long.

Results

Figure 3. Sustained MV over various time windows (30-seconds – red, 60-seconds – green, 90-seconds – purple, 2-minute – cyan) following the onset of apnea. Note that, an apnea of 30-seconds will (by definition) drive MV over a 30-second window down to 0, but will only decrease MV over a 60-second window down to ~35% MV_{PRED} and to less than 60% over a 2-minute window.

Figure 4. Likelihood of an apnea of specific length to decrease MV below the Low MV cutoff over various time windows. Note that a single 10-second apnea has just a 25% chance to decrease MV below 40% in a 30-second window and less than 2% chance to decrease MV below the cutoff over a 2-minute window. Even 60-second apneas have just 20% chance of decreasing sustained MV over a 2-minute window below the 40% MV_{PRED} cutoff.

Conclusions

- ❖ Data showed that while apneas were ubiquitous in post-operative patients, they seldom led to sustained Low MV over clinically relevant time scales. Large compensatory breaths following an apnea generally restored MV to near pre-apnea levels.
- ❖ These findings suggest that detection of even relatively long apneas should not be used to define overall respiratory insufficiency. Nonetheless, some apneas can become dangerous when ignored, as when subsequent sedation decreases compensatory breath size.
- ❖ Complacency to repetitive apnea alarms may compromise patient safety. Instead, RVM data provides a better overall metric of respiratory competence, differentiating compensated from uncompensated apnea, driving better assessment of patient risk and individualization of care.

References

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