Non-Invasive Respiratory Volume Monitoring to Detect and Quantify Opioid-Induced Respiratory Depression and Apnea in Post-Operative Patients

Christopher Voscopoulos, MD1, Jordan Brayanov, PhD2, Jenny Freeman, MD2, Edward George, MD, PhD3

1Brigham and Women’s Hospital, Harvard Medical School, Boston, MA 2Respiratory Informatics, Inc., Waltham, MA 3Massachusetts General Hospital, Harvard Medical School, Boston, MA

Introduction

Evaluating individual patient risk for respiratory depression has previously been difficult due to the lack of objective, non-invasive measurements of respiratory status in the clinical setting. The most common treatment for post-operative pain in the PACU is opioid analgesics. Side effects of opioids, while well recognized, remain a significant risk to patient safety. Opioids can significantly depress respiratory function, leading to opioid-induced respiratory depression (OIRD) which has been shown to correlate with increased rates of overall mortality and mortality in the post-operative setting. Respiratory status is most commonly assessed with respiratory rate (RR), oxygen saturation (SpO2) and subjective clinical assessment. This approach only surrogate indicators of respiratory competence. Obstructive sleep apnea (OSA) has been considered a risk factor for post-operative complications. OSA remains undiagnosed in a significant portion of patients. Many patients without a previous diagnosis of OSA manifest apneic breathing patterns after surgery, a condition termed “Post-Operative Apnea” (POA). POA may occur in patients with undiagnosed OSA, or as the result of a unique combination of central, obstructive, or combined apnea which may be related to postoperative interventions not present in the sleep lab (i.e. residual arterial opioids, sedatives and oxygen). A novel, non-invasive Respiratory Volume Monitor (RVM), which provides respiratory volume traces and reports real-time measurements of Minute Ventilation (MV), Tidal Volume (VT) and Respiratory Rate (RR) has been developed to address these issues. Here we use the RVM to provide an objective assessment of MV that quantifies the respiratory effect of opioid analgesia and to detect and quantify apneic events. We also studied the relationship between a preoperative diagnosis of OSA and respiratory depression due to OIRD and POA in the Post-Anesthesia Care Unit (PACU).

Methods

In an observational study, digital respiratory traces from an impedance based RVM (Exspiria, Respiratory Motion, Inc., Waltham, MA) were collected from 114 PACU patients after elective orthopedic surgery via a thoracic electrode package (Figure 1). Previously, strong correlations (0.076-0.16, mean ± 0.07 CI for regular and erratic breathing) and high accuracy (avg MV and TV errors <10%, avg RR error <2%) between RVM and “gold-standard” spirometric measurements have been demonstrated in non-intubated patients. Predictive (MV<PRED) was calculated for each patient using Body Surface Area (BSA). “Percent Predicted” was defined as MVBSA*/PRED*BSA. Prior to the administration of opioids, patients were stratified into two categories: “Not-OA” (MVBSA < 80% PRED), “Opioid-inspired MVBSA > 80% PRED. Prior to the administration of opioids, patients were stratified into two categories: “Not-OA” (MV/PRED < 80%), “Opioid-inspired MV/PRED > 80%.” After opioid administration, some patients were seen to have a more dramatic response to opioids manifested as low MV levels. Based on physiologic principals and use of an unsupervised classification strategy, patients were classified as “UnSafe” for MV/PRED when MVBSA>PRED was defined as x apneic/hypopneic events per hour. OIRD was defined as MV/RR > 40 L/min/hour following opioid administration. The association between a preoperative diagnosis of OSA and POA/POD was evaluated.

Results

50 of the 114 patients received opioids. In this cohort, OIRD and POA were studied further.

OPIOD Classification

- Patients who received opioids when MV/PRED > 80% remained “Not-UnSafe” 97% of the time. 72% of patients who received opioids when MV/PRED < 80% became “Unsafe” (MV/RR > 40 L/min/hour). 15/50 patients were identified as “At Risk”, 32/50 were identified as “Not-AI-Risk”.
- At Risk patients were classified as “UnSafe” morphine levels after opioid, whereas the remaining 32/50 At Risk patients did not have any classifiable OIRD. 17/32 “Not-AI-Risk” patients were classified “Not-UnSafe” (MV/RR < 40 L/min/hour).

POA Classification

- OSA diagnosis was only significantly predictive in POA classifying 93% of patients.
- The majority of patient with OSA had MV/PRED < 80% (Figure 3, middle) indicating apneic/hypopneic events per hour.

Conclusions

- RVM provides non-invasive, real-time measurements of MV that quantifies respiratory depression, including the effects of opioids and postoperative apnea.
- MV > 80% prior to opioid administration can predict a drop in MV to potentially “UnSafe” levels (MV/RR > 40 L/min/hour). Lower opioid dosing or multimodal therapy may be considered in this group.
- Pre-operative diagnosis of OSA, traditionally considered to be an indicator of potential post-operative respiratory complications, was shown to be a poor predictor of POA with a sensitivity of 91%.
- Pre-operative diagnosis of OSA was an even worse predictor of OIRD with a sensitivity of 61%.
- Evaluation of a respiratory status with RVM prior to opioid administration should be considered.
- An RVM risk assessment protocol may give providers objective respiratory status information in the PACU to allow for protocol modification or therapeutic interventions.
- Stratification of patient response to opioids and MV trend analysis may lead to improved pain management protocols and individualized care with the potential to enhance patient safety in the PACU and after discharge to the hospital floor.

Figure 1: An example case demonstrating a potentially dangerous opioid administration pattern in the PACU. (Figure 3A) 53 y/o male (184 cm, 106 kg, BMI 32.1 kg/m2) arrived in PACU with MV ranging from 9.9-11.9 L/min (85.1 to 5.5 %). Shortly thereafter, he transitioned into a repetitive POA breathing pattern (Figure 3A, middle). Then, after the first dose of PCA opioids, his MV breathing pattern (Figure 3A, right) quickly captured his respiratory course (Figure 3B). During the first 15 hour in the PACU, a MV > 80% (green zone) indicates adequate MV. The next period demonstrates the effects of POA with MV trending to just over 40 L/min. When awakened for pain score assessment, MV transiently increases, only to drop to <40 L/min following PCA opioids. The patient remains “UnSafe” for nearly 2 hours, showing apneic/hypopneic episodes (signal (pain score) of 0 out of 10 just prior to opioid dose. Patient is seen to have been discharged from the PACU with an “At Risk” diagnosis (Figure 3C). MV trends (Figure 3D) are presented in Figure 3. RVM has the least event-specific information, remaining between 8% and 20 breaths/min, providing no indication of this POA or respiratory insufficiency. SpO2 remained ≥95% except during a single, transient decrease to 92%.

Figure 2: Pre-op OVM vs. 4-hour PACU.

Figure 3: Example traces for a PACU stay demonstrating “At Risk” (MV/PRED) and “UnSafe” (MV/RR) in relation to opioid dosing.

Figure 4: Sensitivity and Specificity for Pre-op MV as a predictor for OIRD (left), OSA as a predictor for POA (middle) and OSA as a predictor for OIRD (right).