Non-invasive respiratory volume monitoring provides advanced warning of respiratory depression and can be used to reduce false alarms

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Introduction
Timely identification of respiratory depression in the post anesthesia care unit (PACU) is critical to patient safety. A significant challenge in patient respiratory monitoring is the problem of alarm fatigue and the threat posed by measures to reduce alarm fatigue. Pulse oximetry (SpO2) is associated with significant false alarms, often leading to substantive lowering of SpO2 alarm thresholds. However, these false alarms are most often triggered by sensor displacement and not actual respiratory events. Pulse oximetry also suffers from a considerable time delay. Rather than alerting staff to a patient’s deteriorating respiratory condition, genuine SpO2 alarms are usually triggered only when the patient is already in respiratory distress1. A novel respiratory volume monitor (RVM) provides continuous, real-time measurement of minute ventilation (MV), tidal volume (TV) and respiratory rate (RR) in non-intubated patients. Here we assess the ability of the RVM to capture respiratory depression in advance of low SpO2 and with fewer false alarms.

Methods

Figure 1: A non-invasive Respiratory Volume Monitor (RVM, Explores, Respiratory Motion, Inc.) that provides continuous, real-time, non-invasive measurements of MV, TV and RR. Figure shows standard electrode placement. One electrode is placed at the sternal notch, another is positioned on the upper chest and the third is placed in the right mid-axillary line at the level of the xiphoid.

RVM and SpO2 data were collected at 1-minute intervals from 240 patients undergoing elective joint replacement surgery (130 females, age: 66.8±10.3yrs, BMI:29.6±5.7 kg/m2). RVM data were collected via standard placement of an electrode padset on the thorax, as shown in Figure 1. SpO2 data were collected from records generated by the electronic health monitor. The study was purely observational and patients were managed according to standard care. “Predicted” MV, TV and RR were calculated for each patient based on standard body surface area (BSA) formulas for non-intrusive ventilation under baseline conditions. Ventilation below 40% of MVpred was defined as low minute ventilation (MV) and regarded as a threat to patient safety if sustained. “Low SpO2,” defined as a recorded SpO2 value lower than 90% and was designated as an alarm condition for the pulse oximeter. “Low SpO2” lasting for more than two minutes was considered a “desaturation event.” “Low SpO2” lasting for less than two minutes was considered a “false alarm.” Multifactor analysis of variance (MANOVA) was used to evaluate differences in clinical populations, and unpaired one-sided t-tests were used to compare measurements across groups. Pearson correlations were used to evaluate intra-variable dependencies.

Results

The remaining 18 events were the events for a desaturation event and were concentrated in 15 patients (Figure 3A). The longest such episode lasted for 12 minutes. The RVM showed that 11 of the 18 desaturation events coincided with excessive patient motion and high MV, and that only 7 events (1 per patient) were “true desaturation” events, (true indications of respiratory depression, Figure 3B).

Each real desaturation event was preceded by “LMV” by an average of 16.74±6 min (mean±sem), as illustrated in Figure 4. The level of “LMV” was strongly correlated with the time before an SpO2 alarm sounded (r=0.77, p<0.05, Figure 5). While MANOVA found no difference in the demographics of the populations with real desaturation events versus false alarms (p>0.3 for height, weight, age, BMI, sex), the length of stay in the PACU for the group with real desaturation was significantly longer (17 f/16 vs. 13±4.18 mins, p<0.05).

Conclusions

Improvements in SpO2 monitoring equipment and conservative use of alarm limits have decreased false alarms, yet, this study showed that >90% of SpO2 alarm conditions in the PACU were most likely false. Continuous MV monitoring gives advanced warning of developing respiratory depression due to opioids, sepsis, or other factors and provides early point-of-care data for caregivers to modify opioid dosing or other interventions to prevent progression of respiratory depression to the point of true desaturation and severe compromise. The RVM has the potential to improve patient safety and satisfaction and reduce the length of stay in the PACU as associated with a true desaturation event.