Using Respiratory Volume Monitoring to identify respiratory compromise in high risk obstetric patients

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Introduction

- Previous modalities identifying respiratory depression (RD) include pulse oximetry (SpO_2), capnography (Capno, comprised of $EtCO_2$ & respiratory rate - RRcap) and clinical assessment, all indirect measurements, i.e. late indicators of RD.
- Respiratory Volume Monitoring (RVM) provides a direct quantitative measure of ventilation in non-intubated patients.
- The current study evaluates the utility of RVM monitoring in post-partum patients while minimizing nuisance alarms when compared to SpO_2 and Capno.

Methods

- 77 high risk parturients scheduled for cesarean delivery receiving neuraxial anesthesia with opioids were enrolled.
- Inclusion criteria were BMI > 35 kg/m^2, with any following risk factors (pre-eclampsia, gestational hypertension, diabetes, and OSA).
- MV was measured by RVM (ExSpiron1Xi, Respiratory Motion Inc, Watertown, MA) and presented as % of predicted MV (%MVpred) based on body surface area.

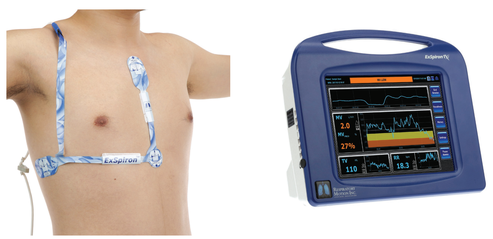


Figure 1. Non-invasive RVM that provides continuous, real-time measurements of MV, TV, and RR. Figure shows standard PadSet placement: sternal notch, xiphoid, and right mid-axillary line at the level of the xiphoid.

- Low MV was defined as MV < 40% of MVpred for ≥ 2 min. Low MV resulted in an audible alarm as an indication of RD.
- SpO_2 , end tidal CO_2 ($EtCO_2$) & respiratory rate from capnography (Capno RR) were measured continuously (LifeSense, Nonin Medical Inc) with defined alarm thresholds (Table 1). Alarm thresholds were set to SpO_2 < 90%, Capno RR < 8 bpm or Capno RR > 30 bpm, and $EtCO_2$ < 15 mmHg or $EtCO_2$ > 45 mmHg.
- Alarm rates were compared across the three monitoring modalities.

Results

	RVM	Pulse Oximetry	Capnography
Patients	77	77	77*
Monitored Hours/ Study Hours (%)	1364/1567 (87%)	965/1567 (62%)	203/1567 (13%)
Alarm-free hours (% of Monitored Hours)	1251 (92%)	431 (44.7%)	3 (1.8%)
Average time between false alarms	271 hrs	12.5 min	2.6 min

Table 1. Table of monitoring times for RVM, pulse oximetry, and capnography. "Study hours" is the total duration that any one or more of the three physiologic study modalities were in use. "Monitored hours" is the fraction of the study time that the device was acquiring physiological values. Alarms were defined as: 1) RVM: true alarms as MV < 40% of MVpred for ≥ 2 min with false alarms generally caused by padset misplacement, 2) SpO_2: true alarms as pulse ox < 90% for ≥ 5 min, with false alarms generally due to intermittent probe dislodgement, 3) Capnography: true alarms as RR < 8 or > 30 (≥ 30s) and as $EtCO_2$ <15 or > 45 mmHg for ≥ 2 min, with false alarms likely due to nasal cannula dislodgement. *33 patients refused capnography monitoring due to discomfort, after initial attempt to place cannula.

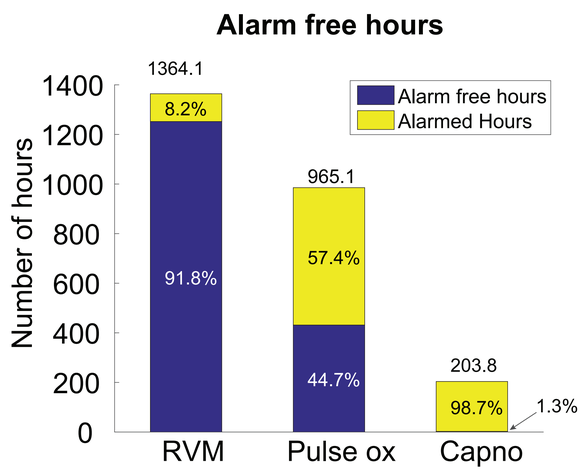


Figure 2. Alarm free hours are the number of monitored hours between each alarm.

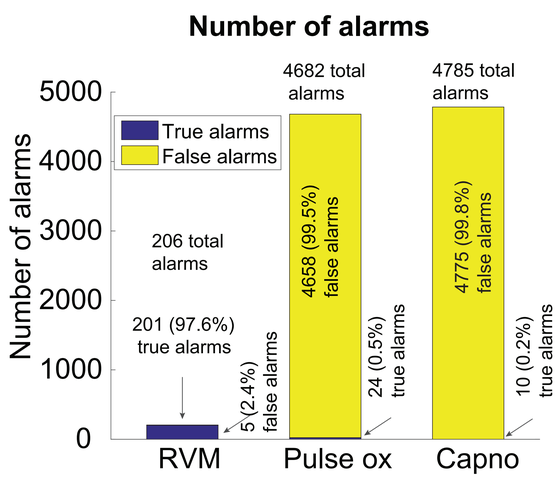


Figure 3. Number of alarms for each monitoring technology.

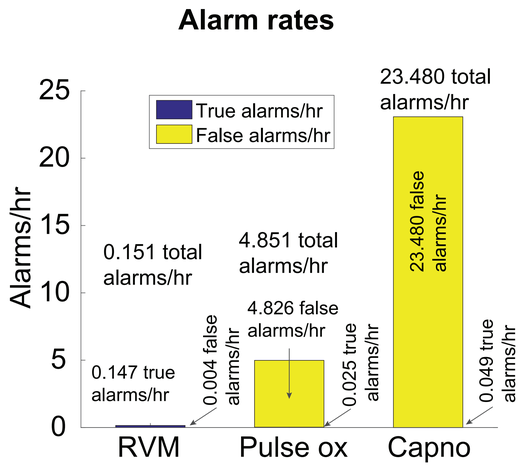


Figure 4. Alarm rates are calculated by the number of alarms divided by monitoring hours, for each monitoring technology and alarm type (total, true, and false alarm rates).

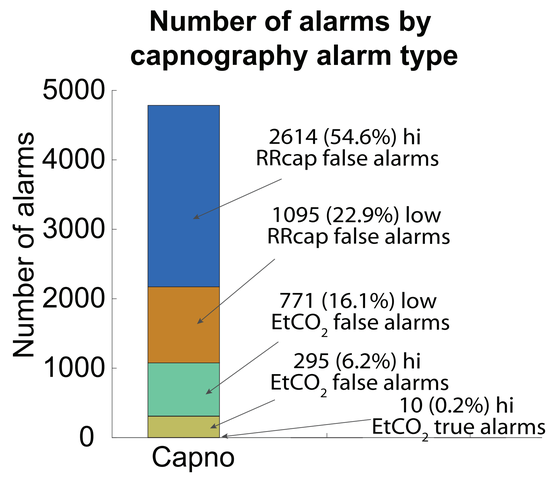
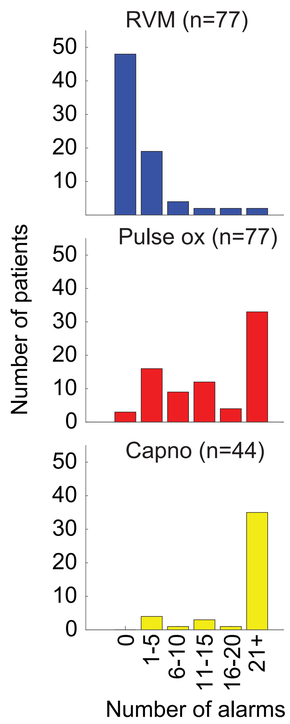


Figure 5. Capnography alarms are further separated into each alarm category. Number of alarms and percentage of total alarms are presented.



Alarm distribution for monitored patients

Figure 6. Distribution of patients with specific number of alarms for each monitoring technology. RVM had a greater number of patients (48/77 patients) with no alarms compared to SpO_2 (3/77 patients) and Capno (0/44 patients). *33 patients refused capnography monitoring due to discomfort, after initial attempt to place cannula.

Conclusions

- RVM provided useful respiratory data in post-partum patients and generated actionable alarms. Here we confirmed that monitoring technologies such as pulse oximetry and capnography produce excessive alarms that contribute to alarm fatigue, with 5 and 23 false alarms per hour, respectively.
- Conversely, monitorign with the RVM, a nurse caring for 4 patients would experience only 1 false alarm every 2 weeks. High false alarm rates and low sensitivity of other monitoring technologies reduce their utility in the clinical setting to identify important respiratory depression events.
- Furthermore, alarm fatigue can lead to patient and staff non-compliance with any monitoring technology. Here, we show that the RVM had a greater rate of patient and staff compliance compared to pulse oximetry and capnography, the latter of which was tolerated by patients only 13% of the time.
- Respiratory Volume Monitoring has the potential to improve patient safety without a negative impact on workflow while decreasing alarm fatigue.

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