比较非侵入呼吸量监测仪和二氧化碳监测仪监测志愿者呼吸状态改变的能力

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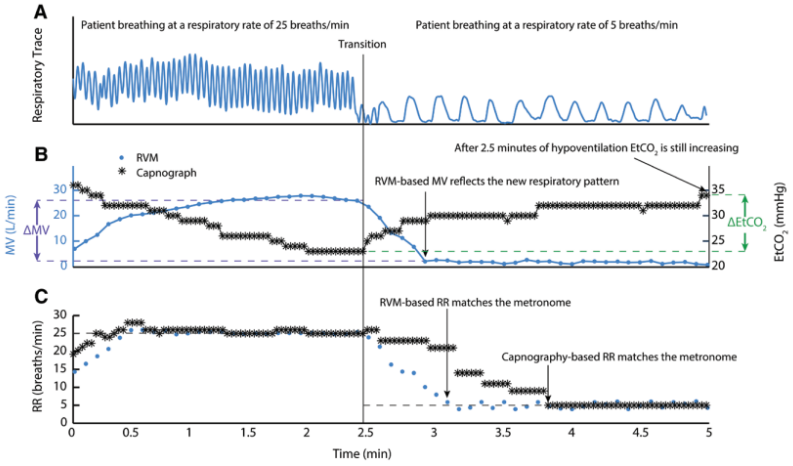
背景：目前呼吸监测技术如脉搏血氧饱和度测定和二氧化碳图辨别非插管患者呼吸功能损害早期症状是不充分的。脉搏血氧合理使用时，会提醒护理人员低血氧症危险。然而去饱和作用明显滞后于换气不足，错误警报导致报警疲劳。二氧化碳图测量呼吸末二氧化碳（$EtCO_2$）和呼吸频率（RR），由于多种原因而尚未普遍使用，原因包括无法将呼吸功能损伤程度和 $EtCO_2$ 可靠联系起来，患者依从性差等。2015 年麻醉报告证明严重并发症与呼吸损伤相关。麻醉患者安全基金会强调需要改进监测方式，以便“没有患者因阿片类药物诱发呼吸抑制受到伤害”。最近获得 FDA 批准上市的一款非侵入呼吸量监测系统（RVM）可以持续、准确监测实际呼吸参数：潮气量、呼吸频率和每分钟通气量（MV）。本研究比较二氧化碳图和 RVM 监测呼吸参数变化的能力。

方案：RVM 测量值（MV,RR）和二氧化碳图测量值（$EtCO_2$,RR）同时收集 48 名志愿者数据，其中二氧化碳图采用两种取样方法（鼻管和内嵌传感器的呼吸嘴）。每位受试者在 3 种不同规定的呼吸频率（缓慢[$5min^{-1}$]，正常[$12.6\pm0.6min^{-1}$]，快速[$25min^{-1}$]）进行 6 次呼吸。

结果：呼吸频率按照要求转变后，RVM 在 37.7±1.4s 内达到新稳态值，而 $EtCO_2$ 变化明显更慢，通常在 2.5min 前达到渐进值。稳定呼吸期间，RVM 和二氧化碳图测量得到的呼吸频率高度相关（R=0.98±0.01，bias=$0.21\pm1.24min^{-1}$（$RR_{二氧化碳图}$-RR_{MV}））。MV 的变化与 $EtCO_2$ 的变化呈负相关。然而呼吸频率转换时，MV 的大变化对应 $EtCO_2$ 的变化较小（鼻管和呼吸嘴：灵敏度 $\Delta EtCO_2/\Delta MV=-0.71\pm0.11$ 和 -0.55 ± 0.11）。鼻管得到 $EtCO_2$ 测量结果平均比呼吸嘴高 4mmHg。

结论：在监测非插管患者呼吸变化时，RVM 得到的 MV 比二氧化碳图响应更迅速。早期监测可以提早干预并降低呼吸抑制并发症的频率和程度。



A Comparison of Measurements of Change in Respiratory Status in Spontaneously Breathing Volunteers by the ExSpiron Noninvasive Respiratory Volume Monitor versus the Capnostream Capnometer

Background: Current respiratory monitoring technologies such as pulse oximetry and capnography have been insufficient to identify early signs of respiratory compromise in non-intubated patients. Pulse oximetry, when used appropriately, will alert the caregiver to an episode of dangerous hypoxemia. However, desaturation lags significantly behind hypoventilation and alarm fatigue due to false alarms poses an additional problem. Capnography, which measures end-tidal CO_2 ($EtCO_2$) and respiratory rate (RR), has not been universally used for non-intubated patients for multiple reasons, including the inability to reliably relate $EtCO_2$ to the level of impending respiratory compromise and lack of patient compliance. Serious complications related to respiratory compromise continue to occur as evidenced by the Anesthesiology 2015 Closed Claims Report. The Anesthesia Patient Safety Foundation has stressed the need to improve monitoring modalities so that "no patient will be harmed by opioid-induced respiratory depression." A recently available, Food and Drug Administration–approved noninvasive respiratory volume monitor (RVM) can continuously and accurately monitor actual ventilation metrics: tidal volume, RR, and minute ventilation (MV). We designed this study to compare the capabilities of capnography versus the RVM to detect changes in respiratory metrics.

Methods: Forty-eight volunteer subjects completed the study. RVM measurements (MV and RR) were collected simultaneously with capnography ($EtCO_2$ and RR) using 2 sampling methods (nasal scoop cannula and snorkel mouthpiece with in-line $etCO_2$ sensor). For each sampling method, each subject performed 6 breathing trials at 3 different prescribed RRs (slow [5 min^{-1}], normal [12.6 ± 0.6 min^{-1}], and fast [25 min^{-1}]). All data are presented as mean ± SEM unless otherwise indicated.

Results: Following transitions in prescribed RRs, the RVM reached a new steady state value of MV in 37.7±1.4 seconds while $EtCO_2$ changes were notably slower, often failing to reach a new asymptote before a 2.5-minute threshold. RRs as measured by RVM and capnography during steady breathing were strongly correlated (R=0.98±0.01, bias=Capnograph-based RR – RVM-based RR=0.21±1.24[SD] min^{-1}). As expected, changes in MV were negatively correlated with changes in $EtCO_2$. However, large changes in MV following transitions in prescribed RR resulted in relatively small changes in $EtCO_2$ (instrument sensitivity = $\Delta EtCO_2/\Delta MV$ =-0.71±0.11 and -0.55±0.11 mmHg per 1 L/min for nasal and in-line sampling, respectively). Nasal cannula $EtCO_2$ measurements were on average 4 mmHg lower than in-line measurements.

Conclusions: RVM measurements of MV change more rapidly and by a greater degree than capnography in response to respiratory changes in nonintubated patients. Earlier detection could enable earlier intervention that could potentially reduce frequency and severity of complications due to respiratory depression.