Respiratory inductance plethysmography for the reliable assessment of ventilation and sleep apnea phenotypes in the presence of oral breathing

E. Finnsson[1], S.Æ. Jónsson[1], H. Ragnarsdóttir[1], H.M. Þráinsson[1], H. Helgadóttir[1], J.S. Ágústsson[1], A. Wellman[2], S.A. Sands[2]

1. Nox Research, Nox Medical, Reykjavík, Iceland,
2. Division of Sleep and Circadian Disorders, Department of Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, United States

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halla@noxmedical.com

Introduction

Ventilatory phenotypes of OSA may be important for guiding therapy and methods now exist for extracting these phenotypes from the clinical PSG [1]. However, determination of these phenotypes is predicated on accurate measurements of airflow.

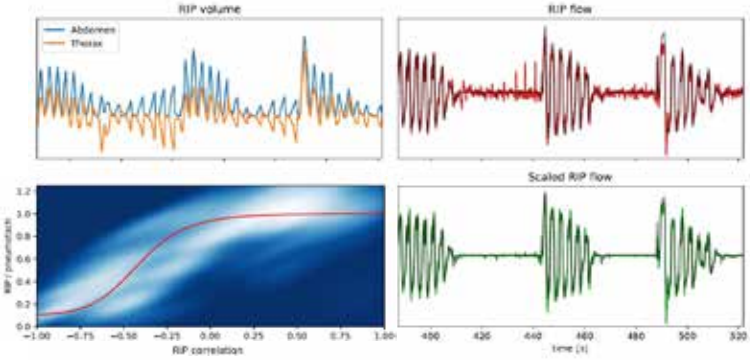
Many patients with OSA exhibit a substantial amount of oral (mouth) breathing during sleep [2, 3] and this oral breathing is not captured with nasal cannula airflow measurements, reducing the ability to determine ventilatory phenotypes from the nasal cannula signal. On the other hand, RIP measures lung volume changes and thus is resistant to the route of breathing.

In this study, we test the hypothesis that changes in minute ventilation can be estimated more accurately with RIP than with nasal cannula in the setting of oral, or combined oronasal, breathing.

Methods

Breathing was recorded using concurrent oronasal pneumotachograph (gold standard), thoracic and abdomen RIP (DC-coupled) and nasal cannula. The minute ventilation derived from the RIP and nasal cannula were compared to the minute ventilation from the pneumotachograph.

Although the RIP signals were correctly calibrated the paradoxical movements measured at the thorax and abdomen during obstructive apneas tend not to cancel exactly. To correct for this a data-driven approach was used where the RIP-pneumotach discrepancy of 39 full night PSGs was calculated as a function of intra-belt correlation (see heat map below). The observed relationship was then described by a logistics function (red line) and used to scale the RIP flow during obstruction.



This study consists of two parts: a case study and a supporting breathing route experiment.

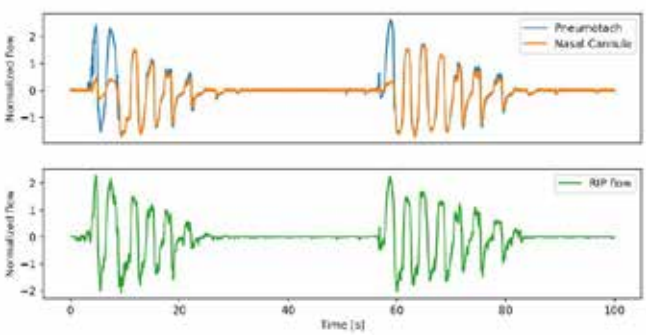
Case patient: In a patient with AHI=59 events/hr in whom pervasive, intermittent oral breathing was recognized on a specialized PSG (discrepancy between cannula and oronasal flow), we assessed and compared changes in nocturnal ventilation via the three sensors.

Breathing route experiment: Four subjects, age 23-40, performed an intermittent breathing route test encompassing nasal, oral, and combined oronasal breathing for ~5 min each during supine wakefulness.

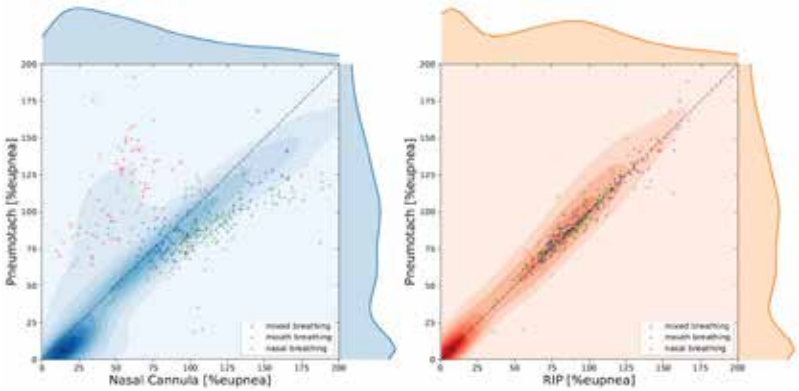
Conclusion

In the context of intermittent oral breathing seen pervasively in sleep apnea, changes in ventilation can be more accurately measured with RIP than with a nasal cannula. Careful assessment of RIP ventilation may provide reliable sleep apnea phenotyping for the clinical setting.

Results



Comparing the flow recorded with the nasal cannula and RIP to the pneumotachograph, shows that the patient tends to take the first recovery breaths after an apnea through the mouth. The nasal cannula underestimates the flow in these breaths while the RIP captures them accurately.



The joint probability density plots show the relationship between the two alternative flow sensors and the pneumotachograph for the breaths of the case patient during a full night's sleep study.

The labeled points indicate the minute ventilation in each breath of the breathing route experiment, making it possible to interpret the unlabelled breaths of the full night sleep study.

We note that the minute ventilation derived from the cannula is underestimated during mouth breathing (peninsula and the red dots), biasing the whole plot. The minute ventilation recorded with the RIP belts is immune to this effect and is unbiased with respect to the pneumotachograph.

Case patient: Across the 4620 breaths measured on PSG, cannula ventilation correlated modestly with the gold standard (r=0.84); the correlation was improved with RIP (r=0.90). The nasal cannula—but not RIP—systematically underestimated ventilatory recovery after events (ensemble-average; nasal cannula=147%mean, RIP=191%mean, gold standard=203%mean), leading to the interpretation of lower loop gain (low overshoot).

Breathing route experiment: Across the N=88±14 (mean±SD) breaths measured, RIP ventilation correlated strongly with the gold standard oronasal ventilation (mean r=0.97, range 0.95-0.98). The cannula showed significantly lower correlation of (mean r=0.25, range −0.04 to 0.46).

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