# Non-invasive Vision-based Pulmonary Evaluation of Sleep Disordered Breathing Through Visualization of Thermal and CO2 Flow

S. Transue[1], O. Diala[2], N. Friedman[3], A. C. Halbower[4], M. Choi[1]; [1]Computer Science and Engineering, University of Colorado Denver, Denver, CO, United States, [2]Department of Pediatric Otolaryngology, Children's Hospital Colorado, Aurora, CO, United States, [3]Department of Otolaryngology, Children's Hospital Colorado, Aurora, CO, United States, [4]Pulmonology - Pediatric Sleep Medicine, Children's Hospital Colorado & Univ of Colorado, Aurora, CO, United States.

**Corresponding author's email: shane.transue@ucdenver.edu**

Background: Sleep disordered breathing (SDB) is a prevalent problem associated with poor sleep quality, leading to decreased cognitive function, poor school performance, and cardiovascular risks. The “gold standard” is diagnostic polysomnogram (PSG), that uses multiple cardiorespiratory sensors (nasal cannula, thermistors, transducer belts) requiring numerous contact points (tape/belts) which disturbs children, causing crying and clogged nasal cannulas. This obtrusive form of monitoring may also impede airflow during sleep in smaller children, thus altering natural breathing patterns. To address these issues and potentially identify new ways to measure altered breathing patterns, we introduce a novel wireless, non-invasive diagnostic imaging software tool that converts thermal $CO_2$ images to measured flow signals. Hypothesis: Thermal and $CO_2$ visual flow analysis will non-invasively, accurately, and continuously measure breathing and detect obstructive or central flow limitation from mouth or nostrils in pediatric subjects. Methods: A prospective study of 20 children undergoing overnight PSG were enrolled (approved by the Colorado Multiple Institutional Review Board). Expiratory airflows are visualized, tracked, and quantified through thermal imaging targeting the $CO_2$ spectral band (3-5[µm]). The spatially tracked exhale flows are then converted into continuous waveforms representing exhale episodes. Synchronized capture of thermal image, 3D point-cloud, and PSG data are directly integrated into the overnight sleep study at Children’s Hospital Colorado. Our software diagnostic isolates spatially tracked exhales within the open-air are algorithmically translated into fine-grained continuous waveforms representing exhale flow used to evaluate direct airflow characteristics of matching apneic events identified through PSG. Results: Preliminary data demonstrates the feasibility of synchronizing visual respiratory flow signals to visually identify normal breathing patterns and apneic events (apnea, hypopnea) in real-time. Our new software isolates visual exhale behaviors, converts them to discrete signals, and synchronizes PSG signals including respiratory (chest, abdomen movement) for correlative analysis. Apnea events and vision identified abnormalities that contribute to SDB are labeled to broaden study diagnostics beyond PSG.

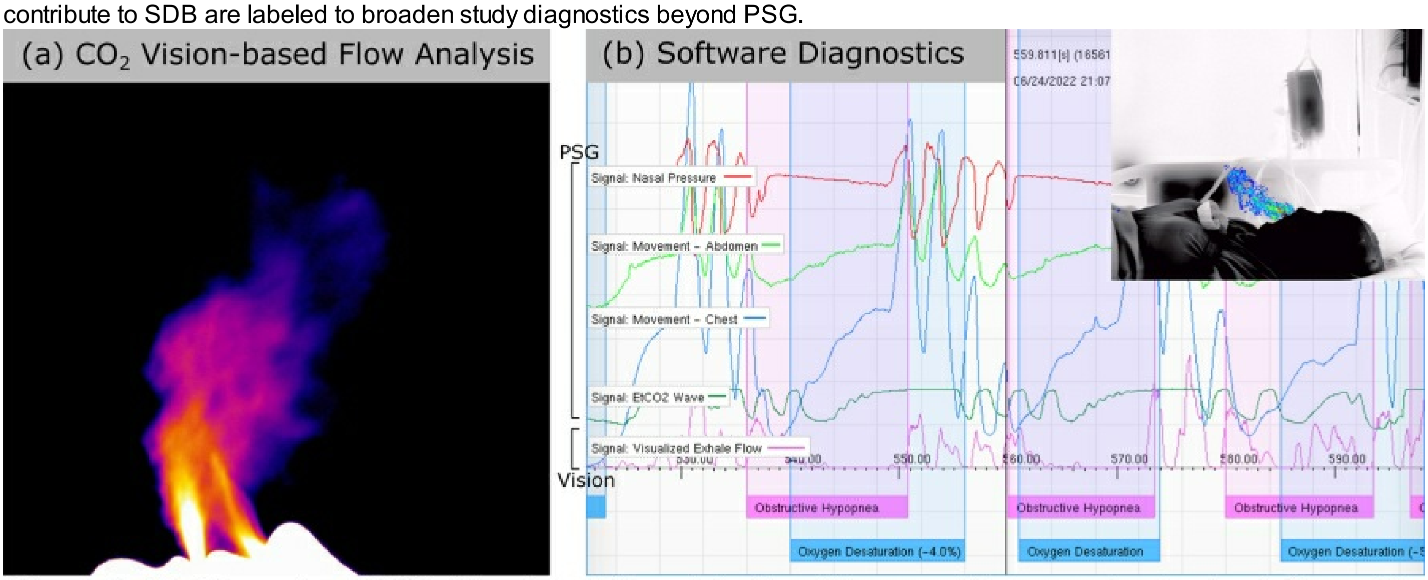


**Figure 1.** (a) Thermal and CO2 vision-based flow detection (b) successful conversion to visual flow with generated output signal and synchronization with PSG. PSG data signals and scored hypopnea and oxygen desaturation events are synchronized and presented for clinical evaluation.

Conclusion: Vision-based evaluation of thermal and $CO_2$ respiratory flow provides novel measurements for daytime breathing abnormalities and SDB diagnosis during PSG. Visual flow data is directly compared with scored PSG gold-standard data to analyze apnea/hypopnea events and evaluate effort-to-airflow signals. This provides a pivotal step towards capturing natural respiration behaviors in child care where PSG and existing airflow evaluation methods significantly influence/inhibit data analysis. Vision-based thermal $CO_2$ analysis directs the evaluation of open-air respiratory flow towards new metrics for exhale volume, location of oronasal sites of obstruction, and adequacy of lung volume.

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