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Airflow:
The Foundation for Accurate OSA Diagnosis

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Executive summary

This white paper explains **why airflow is central to diagnosing obstructive sleep apnea (OSA)**, how airflow can be measured in different ways, and why different methods can lead to different diagnostic results. Drawing on AASM standards and peer-reviewed evidence, we show that airflow-based assessment remains essential for confident, conclusive diagnoses across populations while also forming the basis for precision sleep medicine.

Sleep apnea is an airflow disorder

OSA is a sleep-related breathing disorder characterized by disruptions to airflow, which is why accurately measuring airflow is critical. Yet many modern diagnostic approaches do not measure airflow directly, relying instead on indirect proxy-based technologies.

As sleep testing expands into the home and into broader, more complex patient populations, this shift has the potential to improve access to diagnosis and reduce the gap in care.

The basics of measuring and diagnosing OSA

Sleep apnea events are clinically defined by a measurable reduction in airflow:[1,2,3]

- **Apnea:** A reduction of airflow by at least 90% for a minimum of 10 seconds.
- **Hypopnea:** A reduction of airflow by at least 30% for at least 10 seconds, associated with oxygen desaturation or arousal.

These definitions form the basis of the **Apnea-Hypopnea Index (AHI)** — the standard metric for diagnosing and grading the severity of sleep apnea.

Apnea and hypopnea events must be scored based on validated physiological data sources. Sleep apnea scoring is governed by well-established clinical standards, including the American Academy of Sleep Medicine (AASM) Scoring Manual.[1,2]

AASM scoring rules explicitly define respiratory events based on airflow reduction, supported by oxygen desaturation or arousal. The AASM recommends using a nasal cannula or respiratory inductance plethysmography

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(RIP) to detect apneas and hypopneas, which includes dual thoracoabdominal RIP belts to monitor respiratory effort and score apneas and hypopneas.[1,2]

If a device cannot measure airflow directly, it cannot diagnose sleep apnea by standard clinical criteria.

Ways to measure (or infer) airflow during sleep

Airflow can be assessed directly, estimated from respiratory mechanics, or inferred indirectly.
The method chosen has important clinical implications.

Direct assessment

Oronasal Pneumotachography, the gold standard for airflow measurement, is highly accurate but can be complex to use, demanding careful calibration, is susceptible to drift and leaks, and causes patient discomfort, requiring them to wear tightly sealed oronasal interfaces. This method is not suitable for routine testing as well as being costly.

Estimates of respiratory mechanics

Respiratory inductance plethysmography (RIP) measures chest and abdominal movement to quantify changes in lung volume. When properly calibrated, RIP can measure flow while simultaneously capturing respiratory effort.[4] Calibration is important, but to be able to calibrate, the sensors need to measure a signal that correlates with volume changes. The sensors, therefore, must not break or lose contact during the sleep study. Importantly, RIP supports differentiation between obstruction events (airflow reduction with effort), central events (airflow reduction without effort), and mixed events.[4,5]

Not all RIP implementations, however, are equivalent. A meaningful distinction exists between **volumetric** and **non-volumetric** RIP systems. Volumetric RIP refers to belt designs in which changes in electrical inductance are determined solely by changes in the cross-sectional areas of the thorax and abdomen during breathing, thereby establishing a direct physical relationship to respiratory volume.

Non-volumetric systems, by contrast, produce signals that track the presence of breathing movements but cannot be combined to track changes in volume, and therefore cannot track changes in flow. Only volumetric RIP, when properly calibrated, can yield quantitative measures of ventilation and airflow.[30]

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Indirect assessment

Indirect measurement methods are incomplete because they fail to measure what matters – the change in airflow – and are particularly unreliable when used with patients with comorbidities that affect the majority of sleep apnea patients.[6-9] Proxy methods of measuring airflow are not well-suited for patients with comorbidities because conditions, such as heart failure, obesity, or neuromuscular disease, and treatments like bronchodilators, diuretics, or supplemental oxygen, can alter breathing patterns, airway resistance, and chest wall mechanics, leading to indirect measurements that are less accurate and less reliable.[10-12]

Indirect measurement methods include:

- **Photoplethysmography (PPG) and peripheral arterial tonometry (PAT):** PPG relies on peripheral perfusion, and PAT monitors sympathetic nervous system activation via changes in vascular tone. Neither method can directly measure airflow and can only estimate oxygen saturation and heart rate changes to infer breathing disruptions. PPG is also unsuitable for individuals with various comorbidities as well as posing sensitivities to cold fingers,[14-15] low blood perfusion,[14-15] obesity[11,17] and skin pigmentation,[13] leading to false readings/ false negatives. It is not appropriate as a diagnosis tool but can be helpful in determining when a comprehensive sleep study is indicated.[10,12,14] PAT has limitations in its diagnostic scope, due to lack of accuracy in detecting mild or moderate cases (AHI <15), underestimation of sleep apnea severity, and inability to diagnose central apneas and non-respiratory sleep disorders,[10-12, 14-18] particularly in people of darker skin tones.[15]

- **Nasal cannula:** Nasal cannulas do not directly measure the volume of air entering the lungs but instead measure pressure changes at the nares.

  These pressure changes are not linearly related to flow which can result in an underestimation of the flow magnitude during hypopnea. A nasal cannula cannot detect mouth breathing, and the flow signal is either partially or completely lost when the patient breathes through the mouth. Likewise, nasal cannulas can come loose during sleep, leading to a loss of data for large portions of the night.

- **Jaw movements:** Mandibular jaw movement (MJM) monitoring may slightly overestimate AHI in mild cases and underestimate it in very severe cases compared to standard polygraphy[19].

- **Thermistor:** Thermistors, estimate airflow by detecting temperature changes between inhaled (cool) and exhaled (warm) air. They are good at showing no air movement (apnea) but do poorly at quantifying reduced airflow and accompanying mild respiratory events, often underestimating the severity of hypopneas.

- **Microphone:** Microphones detect sound, not airflow, and do not measure the physiological mechanisms of breathing, thus cannot be a standalone diagnostic tool. They miss critical physiological data required for an accurate clinical diagnosis.

Common airflow measurement approaches

Method & what it measures	Limitations	Key implications
Pneumotachography: Direct, quantitative measurement of airflow	Complex, uncomfortable, and costly	Gold-standard
Nox RIP technology (disposable, snap-on belts): Thoracic & abdominal motion and lung volume→true airflow. Optimized fit has shown improved signal stability.[5]	Nox RIP uses disposable, snap-on dual belts, optimized fit, patented continuous calibration, and advanced signal processing to convert thoracic and abdominal motion into a volumebased respiratory flow signal, unlike standard RIP technology that may be limited by motion and positioning slips and shifts, loose connections, need for calibration, calibration drift, and belt design problems.	High correlation to the flow signal from a pneumotach Patented continuous calibration and advanced signal processing to turn signals from dual RIP belts into a volume-based respiratory signal.[4,5] Volumetric RIP ensures that inductance changes are uniquely related to thoracoabdominal cross-sectional area displacement. As a result, this physical relationship

		to respiratory volume enables reliable calibration and accurate flow derivation[30], leading to results that have been shown to have close agreement with gold-standard pneumotachography
Semi-disposable RIP belts (foldable belts): Thoracoabdominal motion. Derived RIP flow	Fit variability. Folding artifacts and reuse reduce derived flow reliability.	Acceptable for effort detection.
Disposable dual RIP (cut-to-fit): Thoracoabdominal motion. Derived RIP flow	Prone to connection-related issues.	Reasonable correlation with cannula when reliable, but reliability is variable
One or half RIP belt: Motion from either thorax or abdomen	Lacks thoracoabdominal asynchrony	Can not be used to derive flow since paradoxical movements during apneas can not be identified.
PPG, PAT: Autonomic/vascular response	Does not measure airflow & effort	Indirect event inference; unreliable in patients with darker skin tones and those using vasoconstrictive drugs or cardiovascular disease.
Nasal cannula: Relative airflow changes	Mouth breathing, sensor displacement, non-linear	Signal loss with mouth breathing; cannot trust what you see in this signal because flow information is compromised by mouth breathing, which is prevalent in sleep apnea
Mandibular jaw movements (MJM): Reflects respiratory effort	Does not measure airflow	Reliability in complex patient groups is uncertain
Thermistor: Shows cessation of any airflow	Lack sensitivity to detect partial breathing reductions and are prone to measurement errors	Cannot accurately identify flow limitation or mild respiratory events
Microphone: Captures sound	Actual air movement and physiological mechanisms of breathing	Justification for reimbursement rather than delivering physiologically valid measurements

Why Nox RIP?: Not all RIP is created equally

While traditional RIP is a validated, non-invasive standard for monitoring respiratory effort and identifying apnea/hypopnea, not all RIP technology is created equally.[5]

Different setups and equipment produce vastly different results. For example, some traditional RIP only uses a single belt – not capturing data from the full physiological respiratory experience, and some belts are reusable while others are disposable – which can mean compromised signal fidelity damages to belts. Some systems claim to have RIP while in reality they use strain gauges or piezoelectric sensors, which are not as accurate.

Piezoelectric and strain-gauge devices detect local mechanical deformation — voltage or resistance changes — rather than measuring inductance. They therefore lack a well-defined relationship to respiratory volume and cannot be reliably calibrated to yield measurements of tidal volume, and thus airflow. Similarly, not all inductive belt designs are equal: belts in which the conductive element does not fully encircle the body, or that use overlapping layered segments, introduce parasitic inductance that results in a nonlinear and poorly defined relationship between body movement and inductance — making them non-volumetric and precluding reliable flow derivation.[30]

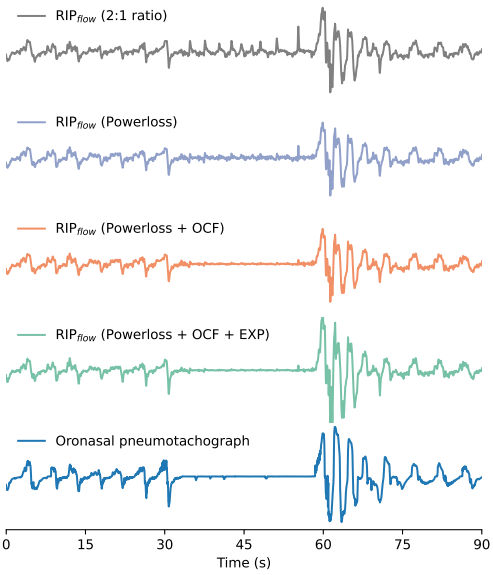
RIP belt design affects the reliability and quality of respiratory signals.[5] Setup often requires manual, time-consuming calibration and is sensitive to changes in body position. Many still assume that an isovolume biocalibration maneuver at the start of the night is the only valid approach, and that calibration becomes invalid as soon as the patient moves. This is addressed through adaptive calibration in Nox software, which continuously recalibrates without requiring an isovolume maneuver.

Nox Medical uses patented continuous calibration and advanced signal processing to turn signals from dual RIP belts into a volumetric respiratory signal.

The clinical value of this approach is supported by published evidence: adaptive calibration combined with corrections for paradoxical motion and nonlinear scaling has been shown to significantly reduce systematic bias relative to oronasal pneumotachography, decreasing overestimation for small breaths from approximately 12% to 2% of eupnea and reducing event-level bias from 9% to 1% of eupnea.[30]

Continuing to advance RIP technology, taking it from an effort signal into a primary diagnostic flow signal is Nox Flow[20-22] – characterized by a number of key innovations, such as comfortable, single-patient use belts that retain signal quality over long wear, connection stability for uninterrupted electrical contact, high-fidelity electronics for fast, accurate signal acquisition for clinical-grade execution, and self-adaptive patented continuous calibration algorithms[23,24] that eliminate paradox and scale signals to match actual flow.
The result is a diagnostic signal that meets the criteria for accuracy, reliability, reproducibility, and scalability in both lab-based and home sleep testing.

"The Nox Flow signal provides a reliable estimate of respiratory flow,[24,25] which, with calibration, has been shown to have close agreement with gold-standard pneumotachography."



The figure illustrates a single obstructive apnea event and how the incremental application of each of the three RIP correction stepsPowerloss calibration, paradox attenuation (OCF) and exponential scaling (EXP)-moves the RIPflow signal closer to the oronasal pneumotachograph gold-standard.[4]

Nox Flow[4,5,20,21] is based on highly sensitive, calibrated RIP signals that:

- Maintain high signal fidelity throughout the night, even with movement or positional changes.[4,5,24,25]
- Are continuously self-calibrating, reducing setup complexity and operator error.[23]
- Provide reliable, repeatable, and physiologically accurate data for all sleep stages and positions.[6-7]
- Are designed to minimize patient disruption, supporting comfort and success rate.

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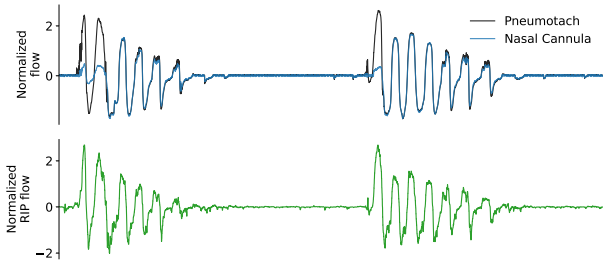

The figure above shows a flow measurement by a pneumotachograph, with the blue trace representing the flow from a nasal cannula overlaid in the black trace. The lower panel displays the Nox Flow signal derived from the thoracoabdominal Nox RIP belts.[24]

What the Nox RIP flow signal makes possible

Beyond accuracy and reliability, RIP signals lead to advanced metrics like validated scoring of arousals and sleep staging from a home sleep study and ventilatory burden while underpinning Nox's novel AI solution,[21] DeepResp FDA-cleared and CE-marked medical device software, which enables an AHI that closely aligns with a full PSG in diverse patient groups, helping reduce underestimation of severity and missed diagnoses.[7,23,24,26]

Current research increasingly focuses on four physiological traits thought to contribute to sleep apnea pathophysiology: upper-airway collapsibility, high loop gain (instability of ventilatory control), arousal threshold (the ease with which a sleeper awakens in response to respiratory disturbance), and pharyngeal muscle responsiveness. These traits help explain why sleep apnea develops, why it presents differently between patients, and why treatment effectiveness differs — and accurate measurement of airflow and respiratory effort is a prerequisite for estimating them.[30]

In addition to delivering actionable insight at scale, the RIP flow signal enables polysomnographic endotyping[27]—a method that identifies the key physiological traits ("endotypes") driving each patient's sleep-disordered breathing. This is the key to unlocking the future of precision medicine.

Not all sleep apnea is the same, and treating it like a single condition leads to trial-and-error therapy and inconsistent outcomes.[25] Nox Flow enables providers to move beyond severity-based assessment of sleep apnea and into mechanism-based assessment, enabling them to create facilitating targeted, data-driven care plans tailored to each patient's physiology.

Research shows these traits can guide precision sleep medicine by matching patients to therapies most likely to be effective.[3,26-29] Although further research and clinician guidance are needed on how to interpret trait data and predict therapy responses, endotyping shows promise in identifying patients likely to benefit from specific treatment based on underlying disease mechanism. Delivered through the Nox Connect platform, DeepResp brings this cutting-edge science into clinical workflows.

Real airflow: Key to accurate diagnosis for all

The proliferation of proxy-based technologies in recent years has been a well-intentioned attempt to reduce barriers to testing access. But only direct, physiologically grounded measurements can build diagnostic confidence and guide the right therapy.

Nox Flow and advanced AI are clinically critical to improving confidence in event detection, gaining better visibility into subtle respiratory patterns, and supporting diverse patient populations and equitable care.
As sleep testing continues to expand beyond the lab, preserving airflow measurement is essential to avoid misclassification, missed diagnoses, and inconsistent results. Airflow is not just another signal — it is the physiological key to unlocking accurate OSA diagnosis for all patients, from the first test.

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