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Flow Limitation/Obstruction With Recovery Breath (FLOW) Event For Improved Scoring of Mild Obstructive Sleep Apnea without Electroencephalography

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Abstract

Objective: Apnea/hypopnea index (AHI), especially without arousal criteria, does not adequately risk stratify patients with mild obstructive sleep apnea (OSA). We describe and test scoring reliability of an event, Flow Limitation/Obstruction With recovery breath (FLOW), representing obstructive airflow disruptions using only pressure transducer and snore signals available without electroencephalography.

Methods: The following process was used (i) Development of FLOW event definition, (ii) Training period and definition refinement, (iii) Reliability testing on ten 100-epoch polysomnography (PSG) samples and two 100-sample tests. Twenty full-night in-laboratory baseline PSGs in OSA patients with AHI with ≥4% desaturations <15 were rescored for FLOW events, traditional hypopneas with desaturations, respiratory-related arousal (RRA) events (hypopneas with arousals and respiratory-effort related arousals) and non-respiratory arousals (NRA).

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DECLARATION STATEMENT
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Results: Scoring of FLOW events in 100-epoch samples had good reliability with intraclass correlation (ICC) of 0.91. The overall kappa for presence of events on two sets of 100 sample events was 0.84 and 0.87 demonstrating good agreement. 80% of RRA and 8% of NRA were concurrent with FLOW events. 56% of FLOW events were independent of RRA events. FLOW stratifies patients in traditional AHI categories with 50%/8% of AHI with ≥3% desaturations (AHI3) <5 and 12%/63% of AHI3 >5 in lowest/ highest tertiles of AHI3 plus FLOW index.

Conclusions: Scoring of FLOW after training is reliable. FLOW scores a high proportion of RRA and many currently unrepresented obstructive airflow disruptions. FLOW allows for stratification within the current normal-mild OSA category, which may better identify patients who will benefit from treatment.

Keywords

Flow Limitation; Breathing Physiology; Home Sleep Apnea Testing; OSA; Scoring

INTRODUCTION

Mild obstructive sleep apnea (OSA) is a highly prevalent disorder that affects quality of life. There is evidence that mild OSA has potentially adverse neurocognitive and cardiovascular complications and that treatment with continuous positive airway pressure (CPAP) improves sleepiness, quality of life and hypertension in some patients.[1] Whether mild OSA increases the risk for adverse outcomes including stroke, heart attacks and death or increases health care utilization as with moderate-severe OSA is unclear.[1–3] Up to 35% of the general population meet criteria for mild OSA,[4] but not all are symptomatic, so it is unclear which patients would benefit from treatment. Adding to the uncertainty, many patients, especially women, have atypical symptoms, including depression, headaches, attention deficits, fibromyalgia, nocturia, and memory loss, which can improve with CPAP therapy.[5,6]

A better understanding of which mild OSA patients benefit the most from treatment could have a large impact on clinical decision making and health care utilization. Improving the diagnostic criteria based on apnea-hypopnea index (AHI) would allow for more focused research that can address this knowledge gap. Polysomnography (PSG) is the reference standard for OSA diagnosis where breathing events with both oxygen desaturations and arousals are considered. As demonstrated by upper airway resistance syndrome (UARS) studies and work on prolonged upper airway obstruction, the current definition for mild OSA using PSG scoring underdiagnoses patients who benefit from treatment.[8,9] In recent years, home sleep apnea testing (HSAT) without electroencephalography (EEG) has supplanted PSG in clinical practice because of its lower cost and ease of administration. HSAT can identify oxygen desaturations, but unlike PSG, does not assess central nervous system arousals or awakenings, forcing the use of desaturation-only criteria. Desaturation-only criteria result in 15– 20% more missed diagnoses compared to criteria including both arousals and desaturations and classify 20–25% of moderate-severe OSA patients as mild or no OSA.[10,11] Women are more likely to be symptomatic despite lower apnea hypopnea indexes, due to more upper airway resistance without oxygen desaturations than men.[5] [8,12] HSAT is only recommended for the diagnosis of moderate-severe OSA because of its insensitivity in mild patients and repeat PSG is recommended after normal HSAT.[7] The increased use of HSAT coupled with insurance rules to use desaturation-only criteria results in classifying many patients as normal or mild OSA, who in fact have more severe disease that would benefit from treatment.

Flattening and reduced amplitude of the inspiratory pressure transducer profile, or flow limitation,[13] is a sign of partial airway obstruction and likely an important marker of obstruction that is not fully utilized by current scoring methods as suggested by the following: 1. Flow limitation correlates well with increased esophageal pressure manometry and upper airway resistance and often anticipates arousals and hypopneas and apneas.[14] 2. Partial airway obstruction is often associated with increased carbon dioxide tension and lower baseline oxygen saturations.[8] 3. Women have higher rates of flow limitation and are frequently symptomatic despite low AHI.[8] 4. Patients with prolonged airway obstruction have as decreased life quality score as OSA patients.[8] 5. Prolonged partial airway obstruction increases the risk of developing high blood pressure by 42% even when AHI is normal.[15] 6. CPAP therapy improves blood pressure and fetal movements in pre-eclampsia patients with increased flow limitation but normal apnea-hypopnea index (AHI).[17,18] 7. CPAP adherence is as high in women as men despite lower AHI, but with more partial airway obstruction.[19] These findings suggest failure to recognize flow limitation by using only AHI for diagnosis likely leads to under-recognition of the full effects of obstructive sleep apnea

To overcome the shortcomings of AHI based diagnosis of OSA especially with HSAT testing, we propose an event measure, Flow Limitation/Obstruction With recovery breath (FLOW), defined by pressure transducer and snore signal without the need for the electroencephalogram (EEG). Since the degree of inspiratory flow limitation varies greatly in patients with similar AHI, we hypothesize that FLOW will allow for stratification within the mild OSA category. As a first step in establishing the utility of FLOW, this paper evaluates the reliability of scoring this event and its correlation with traditional EEG based apneas, hypopneas, respiratory-effort related arousals (RERAs) and other arousals. Future research will be needed to determine the clinical utility of FLOW scoring in stratifying disease burden and improving the diagnosis of clinically significant mild OSA.

MATERIAL AND METHODS

Design

The study had three main elements: 1. Development and refinement of FLOW definition; 2. Reliability testing of FLOW scoring; 3. Evaluation of FLOW properties including overlap with traditional arousal-based scoring events and evaluation of ability to discriminate obstruction compared within current AHI cut-points. The study was approved by the Institutional Review Board of Baystate Medical Center (953872–6).

Polysomnography Samples

Study samples were chosen from multiple random sleep clinic patients diagnosed with mild OSA and prescribed CPAP with full night in-laboratory baseline PSG with the aim to represent different airflow patterns. Mild OSA was defined as respiratory disturbance index (RDI) ≥ 5 defined by apneas plus with hypopneas ≥3% desaturations and/or arousals and respiratory effort related arousals and AHI<15 defined by apneas plus hypopneas with ≥4% desaturations (AHI4). This included patients who would be considered normal or having mild OSA by Medicare rules. PSG recordings included 4 EEG, electrocardiography, electrooculogram, electomyography, thermistor, nasal pressure transducer, chest and abdomen plethsmography and oxygen saturation using Natus Neuroworks at Baystate Medical Center in Springfield, MA. Sleep staging was scored according to 2016 American Academy of Sleep Medicine (AASM) Scoring Manual. Respiratory events were scored while visualizing the full PSG screen including EEG on a two-minute window with pressure transducer low frequency generic DC filter and high frequency filter at 100 Hz. Filters could be adjusted by the rater if artifact affected ability to determine an event. Snore sensitivity was set at 20 μV/mm. Hypopneas were marked if there was a 30% or more decrease in nasal pressure amplitude for at least 10 seconds, and scored as either obstructive hypopnea with arousal or obstructive hypopnea with either ≥3% or ≥4% desaturations if obstructive features of snoring, flow limitation or abdominal/thoracic paradox were present. RERAs were scored if there were a sequence of breaths lasting ≥10 seconds characterized by increasing respiratory effort or by flattening of the inspiratory portion of the nasal pressure leading to an arousal that did not meet criteria for an apnea or hypopnea.

Development and Refinement of FLOW definition

A basic definition for FLOW (Figure 1) was developed taking in consideration prior research on inspiratory flow limitation patterns as a marker of obstruction.[20,21] The duration of event and amplitude criteria were initially chosen by consensus of the authors. To increase the scoring reliability and representation of obstructive events, the definition was further clarified during initial training period. Given the variability of airflow patterns between patients, we developed a full definition below to clarify the scoring of borderline events. The final definition with expanded rules below was then used for the final reliability testing. Figure 1 (FLOW Definition and Scoring Samples) A-C demonstrates examples of FLOW events and D-F demonstrates events that would not meet criteria. Figure 2 (FLOW Scoring Rules) shows further examples of FLOW events and Figure 3 (Amplitude Scoring) demonstrates how to measure amplitude of inspiration.

Full FLOW Definition

Score FLOW events on the final two breaths before recovery breath if meet the following criteria:

A. Run of at least 2 breaths that have evidence of obstruction

   1. At least 2 breaths with flow limitation as evidenced by inspiratory flattening or scooping. Borderline flow patterns that follow the patient's typical obstructive pattern with progressively decreasing amplitude followed by sudden recovery breath may be scored (figure 2A). Do not score a single larger breath or waxing and waxing that could suggest either normal variation, central physiology (Figure 2B) or an isolated larger breath associated with a limb movement (Figure 2C) or possibly a non-respiratory arousal.

2. At least 2 breaths with moderate-severe snoring or if there is mild snoring that abruptly stops with post event breath is scored.

3. If there is a run of at least 4 flow limited breaths or progressively more obstructed breathing, but there is a transition breath such that one of the final 2 breaths prior to the recovery breath does not meet criteria, can still score if the 2 pre-transition breaths meet amplitude criteria compared to the post transition breath and it is not part of a waxing and waxing increase. Mark the event on all 3 breaths (2 pre-transition breaths and the transition breath). (Figure 2D).

B. Must be followed by a distinct change in breathing pattern with increased amplitude, which we will refer to as "recovery breath"

1. Amplitude is measured from inflection point to peak. Peak is determined by the average of 0.5 seconds of highest values to allow for weighting of artefactual deflections. (Figure 3)

2. Score if 2 breaths with obstructive pattern are followed by post-event breath is 50% larger and if the post breath is a definite recovery breath as evidenced by attributes like rounder, smoother, narrower, and with distinctively different morphology for obstructed breaths

3. Score if 2 breaths with obstructive pattern are followed any doubling (100% increase) in size of post event breath.

C. Meets distance criteria from other events

1. Must be at least 2 breaths before and after another flow limitation event

2. Must be at least 2 breaths after an apnea or hypopnea with >=3% desaturation

3. Can score overlapping with hypopneas with arousals and RERAs that would be unscorable without EEG.

Reliability Testing

The initial training period involved review of definitions and training on scoring of FLOW events on random sample events with different flow limitation profiles. The rater then trained on two sets of 100 event samples with raters marking reason for positive or negative, which were reviewed with the trainer. Finally, raters trained on fourteen 100-epoch sleep study samples, which were reviewed with the trainer between each sample and reasons for discrepancies were discussed. After the initial training period on sample events demonstrated adequate reliability, final testing for reliability was performed on two different 100 event sample tests and ten different 100-epoch sleep study samples by two sleep medicine specialists and one sleep technician. Samples were selected from PSGs of mild OSA patients with different flow limitation patterns in order to fully test the different scoring rules.

For each of the 100 event sample tests, a 2-breath segment was marked in a 2-minute epoch were marked by the trainer (rater 1) for a possible event. Approximately 50 positive and 50 negative samples were chosen for each test. The other 2 raters then scored the segments as either consistent with FLOW or not. Raters scored samples in random order and were blinded to the gender of patient

For ten 100 epoch tests, sleep stages and standard events were manually prescored by sleep technicians using AASM criteria. Raters scored FLOW events in the pre-marked samples and intraclass correlation (ICC) was determined.

For the two 100 sample test events, two-minute PSG samples were marked for a possible event and the rater scored the sample as positive or negative for a FLOW event. For dichotomous classification, the kappa statistic was computed.

FLOW Evaluation

Twenty full night PSG samples in ten women and ten men with mild OSA were evaluated for how often FLOWs were scored at the same time as respiratory related arousals (RRA) (hypopneas with arousals and respiratory effort related arousals (RERAs)), and non-respiratory related arousals in women vs men.

To determine indexes, the 20 studies were rescored by a sleep technician and reviewed by sleep medicine specialist for apneas, hypopneas with 4% desaturations, hypopneas with 3% desaturation, hypopneas with arousals, RERAs, and FLOW events and reviewed by a sleep physician. Indexes were calculated for AHI4, AHI with hypopneas ≥ 3% desaturation (AHI 3), AHI with hypopneas ≥ 3% desaturation or arousals (AHI 3A), respiratory disturbance index with hypopneas ≥ 3% desaturation or arousals plus RERAs (RDI), and FLOW enhanced AHIs (AHI 3_{FLOW} and $AHI4_{FLOW}$).

We evaluated patients with AHI < 5 and ≥ 5 to determine the percentage of patients who scored in the upper, middle and lower tertiles of AHI_{FLOW}.

Statistical Analysis

To assess reliability of scoring, we computed the intraclass correlation coefficient (ICC) for continuous variables[22] and kappa (k) for categorical variables.[23] Landis and Koch provide ranges for interpreting agreement estimates.[24] Values greater than 0.75 are considered excellent, whereas values less than 0.40 are considered poor. All estimates are reported with 95% confidence intervals.

RESULTS

Table 1 shows the agreement between the standard rater (R1) and a sleep technician (R2) and a sleep physician (R3) on FLOW-positive or FLOW-negative scoring of two sets of 100 sample events. In the first trial, kappa values ranged from 0.66 to 0.81. Following additional training and discussion, kappa values for the second trial improved, ranging from 0.72 to 0.84.

To assess agreement for FLOW in epoch samples, 100 epoch samples in 10 sleep studies were evaluated among the same raters using the intraclass correlation (Table 1). ICC values showed excellent agreement with an overall agreement of 0.91 (95%CI: 0.77, 0.97).

In 20 full-night PSG, there were 2,495 FLOW events, 873 hypopneas with arousals, 454 respiratory effort related arousals (RERAs) and 489 arousals. Overall 80% of respiratory-related arousals) RRA and 8% of non-respiratory arousals (NRA) were concurrent with FLOW events with an additional 56% of FLOW events independent from other events (Figure 4). When evaluating average correlations between events in 20 different patients, 80%±15 of RRA, 8%±1 of NRA were concurrent with FLOW events and 53%±16 of FLOW events had no associated events. The effect size was in the moderate range for concurrence of FLOW with HA and isolated flow events suggesting that females may have more HA concurrent with FLOW events than men and men may have more isolated flow events than women. (Table 2).

Comparisons of standard indexes and FLOW enhanced indexes are shown in Table 3. There was no statistical difference in indexes by gender, but there was a trend toward higher AHI3A and RDI in females. In 20 patients, the FLOW indexes ranged from 8.5–47.0 despite narrow AHI4 range of 0.2–8.9. Three, eight, and 17 of the 20 patients had AHI < 5 and would not have been diagnosed with OSA by AHI 3A, AHI3, AHI4 respectively. Adding FLOW index to AHI allowed for more discrimination between patients with AHIs in both the normal and mild ranges of desaturation only criteria in to sub-groups with more or less overall obstruction. (Table 4) 50% of patients with AHI3 ≤5 and 12% of AHI3 ≥5 were in the lowest tertile of $AHI3_{FLOW}$ while 8% of patients with AHI3 ≤5 and 63% of AHI3 ≥5 were in the highest tertile. Similarly $AHI4_{FLOW}$ allowed for stratification within the 17 patients with AHI4 <5, with 41% in the lowest tertile and 24% in the highest tertiles of $AHI4_{FLOW}$.

DISCUSSION

Using samples from mild OSA patients, this study defines and characterizes an EEG-independent event, FLOW, that scores most non-desaturating obstructive hypopneas defined by arousals and respiratory effort related arousals as well as additional periods of inspiratory flow limitation associated with recovery breaths. In 2017, an American Thoracic Society (ATS) workgroup published recommendations for identification of inspiratory flow limitation in sleep studies with the understanding that this type of airflow pattern may have important clinical implications.[13] While our work began prior to the ATS publication and thus did not use their specific definition for flow limitation, our definition of flow-limited breaths is consistent with their criteria. We further expanded their concept to a scorable event type using the recovery breath as a surrogate for sleep disruption in the absence of EEG. This paper sets the foundation for future studies, but does not assess how best to utilize this event in clinical practice.

After a brief training period, there was good scoring reliability between two sleep medicine specialists and one sleep technician. The reliability was higher in the 100 epoch samples than the single event classification. This was expected since context can help determine whether the flow pattern is obstructed or within the normal range for that patient. We also found that once trained adding the scoring of flow events was easily incorporated into the sleep technician's scoring of typical events without adding considerably more time. Our study was limited by the relatively small number of samples and raters. Independent training and testing with multiple raters on samples from more patients will be needed to confirm scoring reliability.

One benefit of FLOW is that scoring relies only on the nasal pressure transducer and snore signals, which is available with both PSG and HSAT without EEG. As this study used PSG samples that may have better signal quality than HSAT, the manual and automated reliability of scoring FLOW in HSAT and PAP device data needs to be confirmed. Current scoring criteria leads to large differences in OSA diagnosis and severity between PSG and HSAT.[10,11] AHI using desaturation-only criteria allows for more uniform scoring, but has lower sensitivity for obstructive physiology. Including FLOW scoring on both HSAT and PSG can make the scoring more equivalent while increasing sensitivity beyond AHI with desaturation criteria. We expect the scoring of FLOW events to be highly automatable since HSAT devices already can assess flow limitation, snoring and amplitude changes. This also allows for scoring of waveform data from positive airway pressure (PAP) devices either manually or ideally generated using automated detection and classification algorithms during therapy. Integrating the principles of FLOW detection into PAP devices may improve therapy algorithms and reporting residual AHI_{FLOW} on compliance data may help with treatment decisions in refractory patients and help differentiate between patients with residual obstructive and central disease.

Current scoring of PSG and HSAT scoring with AHI criteria is limited by the underrepresentation of prolonged partial airway obstruction without distinct events. HSAT, especially often underdiagnoses patients with clinically significant mild sleep apnea due to lack of arousal data. While 53% of FLOW events were not associated with currently scored events, most respiratory related arousals (RRA) and few non- respiratory arousals (NRA) scored concurrently with FLOW events suggesting that FLOW detects obstructive flow disturbances and not breathing changes associated with non-respiratory-related arousals or leg movements. Our sample of 20 patients included 17 patients who would not have been diagnosed with OSA by Medicare criteria including 4% desaturations. Adding FLOW events to AHI3 increased the range of events to 10–48 events per hour which could allow for increased discrimination of OSA severity which may help both the sensitivity and specificity of testing for clinical outcomes.

We did not find any gender differences in FLOW events or sleep indexes suggesting that FLOW can add information about obstructive burden beyond AHI in both males and females. This is consistent with high levels of partial airway obstruction in both men and women.[8] Given 50% of females are in the mild range of OSA when scored with AHI3A and more with desaturation-only criteria, FLOW will likely be helpful in more women to differentiate clinically significant obstructive sleep disordered breathing from normal.[28] Larger studies are needed to fully assess gender differences in FLOW events. While we developed FLOW in mild OSA patients, the addition of FLOW events to patients with more severe disease may also help stratify patients into different phenotypes and risk groups that may inform decisions about which patients with most benefit from treatment.

FLOW events score a range of mild obstructive physiology including hypopneas with arousals in mild OSA, respiratory-effort related arousals in UARS and prolonged partial flow limitation without the use of EEG. Future studies are needed to determine whether the events scored by FLOW are related to clinical outcomes that have been described in UARS and prolonged partial airway obstruction patients. Since FLOW scores many more events than traditional scoring, using it like AHI with a cut-point of 5, would likely lead to a high false positive rate. Instead we expect that to increase the diagnostic sensitivity and specificity as well as to help in risk stratifying patients within the current mild OSA range, that FLOW will be used in combination with other OSA physiological markers. FLOW events may need to be weighted differently in men and women, different races, or obese and non-obese given differing physiology. FLOW events may also have varying importance depending on the outcome tested such as daytime sleepiness or fatigue, disrupted nocturnal sleep, overall quality of life, health care utilization, and risk of hypertension or cardiovascular events. We encourage other researchers to incorporate FLOW and other markers of OSA physiology into their research to gain a better understanding of the effects of mild sleep disordered breathing.

In summary, FLOW is a novel event that more fully represents upper airway obstruction than apneas and hypopneas especially without EEG. FLOW scoring utilizes signals available with both PSG and HSAT. FLOW detects most hypopneas with arousals and less than 3% drops in oxygen saturation, as well as additional events. This paper demonstrates the ability to reliably score FLOW events in PSG studies. Future studies are needed of reliability testing in HSAT studies, to determine how best to clinically use FLOW events, and whether FLOW can help diagnose or risk stratify patients with OSA and inform treatment decisions.

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Abbreviations:

AHI	apnea/hypopnea index
AHI4	AHI defined by hypopneas with 4 % desaturations
AHI3	AHI defined by hypopneas with 3 % desaturations

AHI3A	AHI defined by hypopneas with 3 % desaturations or arousals
$AHI3_{FLOW}$	AHI defined by hypopneas with 3% desaturations plus FLOW index
$AHI4_{FLOW}$	AHI defined by hypopneas with 4% desaturations plus FLOW index
EEG	electroencephalography
FLOW	flow limitation/obstruction with recovery breath
HA	hypopnea with arousal
ICC	intraclass correlation
HSAT	home sleep apnea testing
NM-OSA	normal to mild OSA by desaturation criteria, with at least mild OSA with arousal criteria
NRA	non-respiratory related arousals
OSA	obstructive sleep apnea
PLM	Periodic limb movements
PSG	polysomnogram
R1	rater 1
R2	rater 2
R3	rater 3
RERA	respiratory effort related arousals
RRA	respiratory related arousals (hypopneas with arousals and RERAs)
UARS	upper airway resistance syndrome

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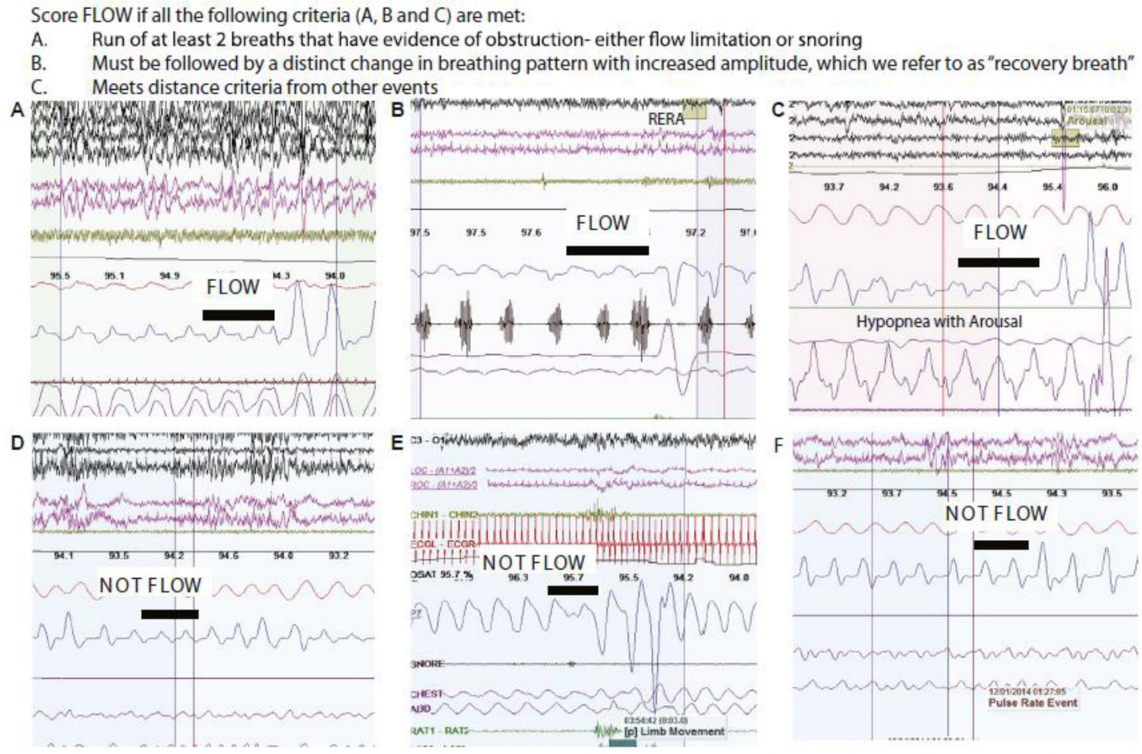

Figure 1.
Flow Limitation/Obstruction With recovery breath (FLOW) basic definition and samples.

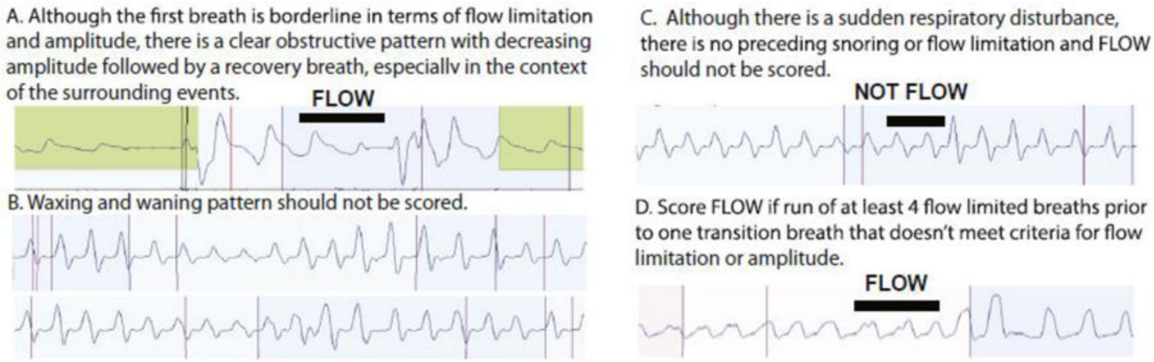

Figure 2.

Flow Limitation/Obstruction With recovery breath (FLOW) rules.

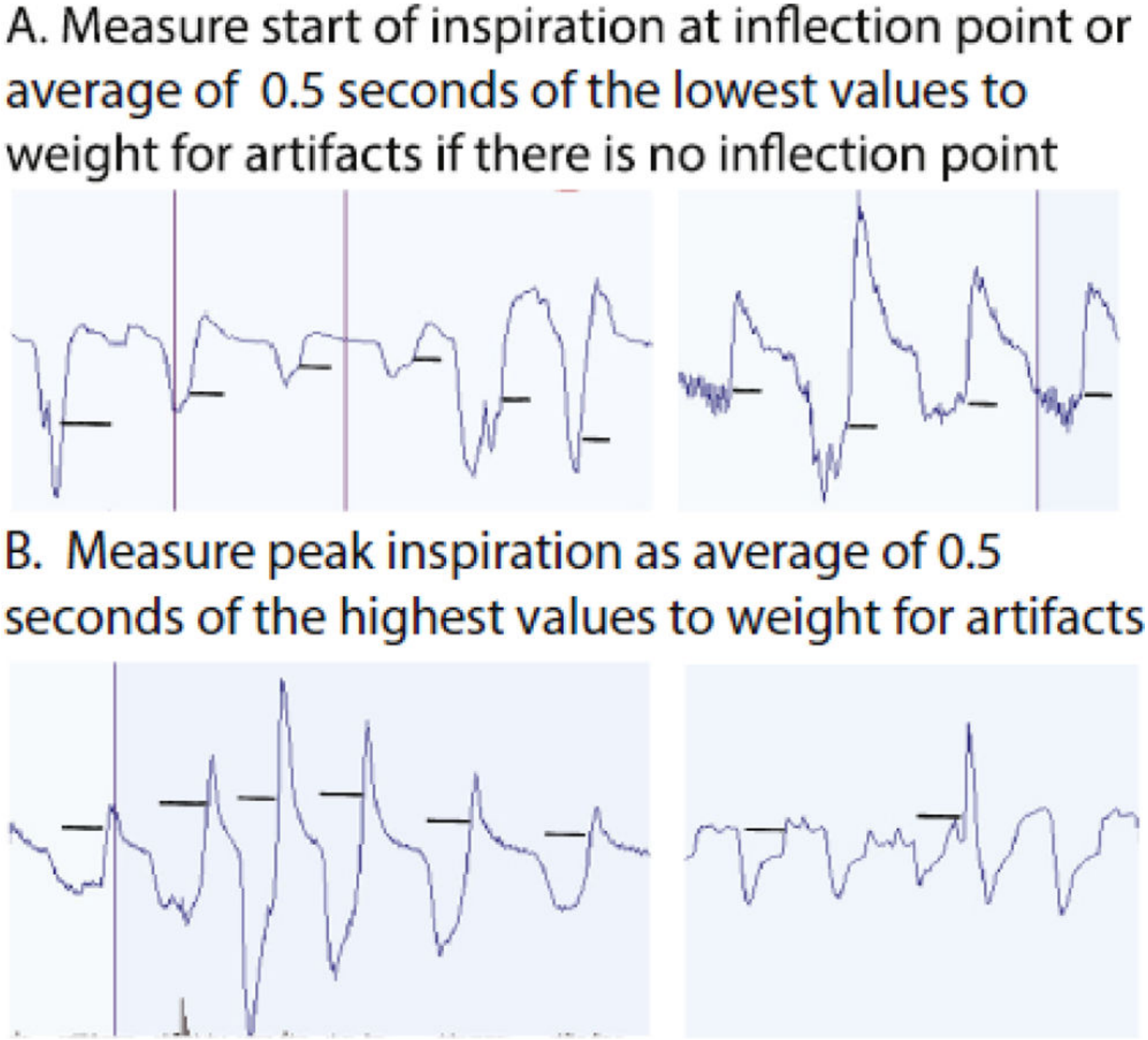

Figure 3.
Measuring start and peak of inspiration.

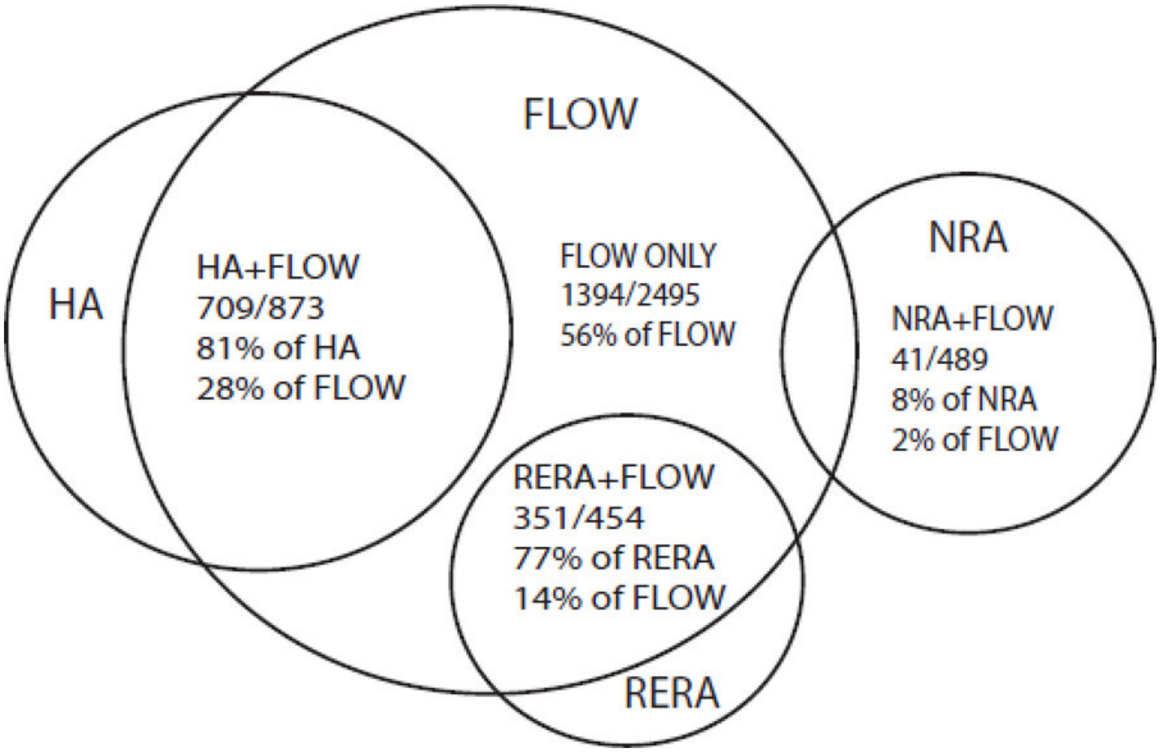

Figure 4.
Concurrence of FLOW with current event types.

Table 1

Reliability Testing of FLOW Scoring.

	Agreement	Kappa	95% CI	p
Trial 1 FLOW Scoring in 100 Samples				
R1 vs. R2	0.85	0.68	0.52, 0.83	< 0.001
R1 vs. R3	0.91	0.81	0.69, 0.93	< 0.001
Overall	0.84	0.66	0.54, 0.78	< 0.001
Trial 2 FLOW Scoring in 100 Samples				
R1 vs. R2	0.92	0.84	0.73, 0.95	< 0.001
R1 vs. R3	0.86	0.72	0.58, 0.86	< 0.001
Overall	0.87	0.73	0.62, 0.84	< 0.001
	ICC		95% CI	p
FLOW scoring in 100-epoch Samples (n = 10)				
R1 vs. R2	0.93		0.75, 0.98	< 0.001
R1 vs. R3	0.93		0.75, 0.98	< 0.001
Overall	0.91		0.77, 0.97	< 0.001

FLOW: Flow Limitation/Obstruction With recovery breath event; R1, rater 1; R2, rater 2; R3, rater3; CI, confidence interval.

Table 2

Concurrence of Traditional Events with FLOW.

Concurrent Event	Overall	Females	Males	Effect size
	mean (%) ± SD	mean (%) ± SD	mean (%) ± SD	
HA	79 ± 21	83 ± 14	75 ± 27	0.38
RERA	78 ± 17	77 ± 13	79 ± 20	0.10
NRA	8 ± 1	7 ± 10	9 ± 8	0.25
FLOW alone	53 ± 16	50 ± 13	56 ± 19	0.41

HA: Hypopnea with arousal; RERA: Respiratory Effort Related Arousal; NRA: Non-respiratory arousal; FLOW: Flow Limitation/Obstruction With recovery breath

Table 3

Comparison of Sleep Event Indexes in 20 Polysomnography

Index	Overall *mean ± SD*	Range
AHI4	2.6 ± 2.7	0.2 – 8.9
AHI3	4.7 ± 4.0	0.2 – 13.8
AHI3A	12.8 ± 6.8	3.4 – 24.9
RDI	17.4 ± 8.8	9.1 – 40.9
FLOW index	23.7 ± 9.7	8.5 – 47.0
$AHI4_{FLOW}$	26.3 ± 10.6	10.1 – 48.4
$AHI3_{FLOW}$	28.4 ± 11.6	10.9 – 54.5

AHI, apnea/hypopnea index; AHI4, AHI with hypopneas with ≥ 4% desaturations; AHI3, AHI with hypopneas with ≥ 3% desaturations; AHI 3A, AHI with hypopneas with ≥ 3% desaturations or arousals; FLOW, Flow Limitation/Obstruction With recovery breath; AHI $_{FLOW}$, AHI plus FLOW

Table 4

Stratification of Obstructive Burden with AHI_{FLOW} Within AHI Cut-points.

	$AHI4_{FLOW}$ Tertile Range		
	10.1 – 21.9	**22.0 – 29.9**	**30.0 – 49.0**
AHI4	**n (%)**	**n (%)**	**n (%)**
< 5.0	7 (41.2)	6 (35.3)	4 (23.5)
≥ 5.0	0 (0)	1 (33.3)	2 (66.47)
	$AHI3_{FLOW}$ Tertile Range		
	10.9 – 23.9	**24.0 – 30.9**	**31.0 – 54.9**
AHI3	**n (%)**	**n (%)**	**n (%)**
< 5.0	6 (50.0)	5 (41.7)	1 (8.3)
≥ 5.0	1 (12.5)	2 (25.0)	5 (62.5)

$AHI4_{FLOW}$, apnea hypopnea index(AHI) with hypopneas with ≥ 4% desaturations plus FLOW event index; $AHI3_{FLOW}$, apnea hypopnea index(AHI) with hypopneas with ≥ 3% desaturations plus FLOW event index