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Original Article

A systematic comparison of factors that could impact treatment recommendations for patients with Positional Obstructive Sleep Apnea (POSA)

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ABSTRACT

Objective/Background: Systematically compare four criteria for Positional Obstructive Sleep Apnea (POSA) based on AASM 2007 and 2012 hypopnea scoring definitions.
Patients/Methods: 142 records acquired by in-home polysomnography (Sleep Profiler PSG2™) were retrospectively analyzed using AHI based on the American Academy Sleep Medicine 2007 and 2012 criteria (AHI^{2007} and AHI^{2012}). Positional obstructive sleep apnea (POSA) was characterized using four criteria: Amsterdam Positional OSA Classification (APOC), supine AHI twice the non-supine AHI (Cartwright), Cartwright plus the non-supine AHI < 5 (Mador), and the overall AHI severity at least 1.4 times the non-supine severity (Overall/NS-AHI).
Results: Correlations between the Cartwright and Overall/NS-AHI criteria increased with the inclusion of a more relaxed definition of hypopneas ($AHI^{2007} = 0.79$ and $AHI^{2012} = 0.86$, $P < 0.00001$). The prevalence of POSA based on the Cartwright and Overall/NS-AHI criteria was approximately 60% in those with at least mild OSA by $AHI^{2007}$and AHI^{2012}. A 16% reduction in POSA prevalence for AHI^{2012} vs. AHI^{2007} was attributed to the increased incident of mild OSA. For identification of those expected to have 25% or 35% reductions in SDB severity with positional therapy, Cartwright and Overall/NS-AHI exhibited the strongest sensitivity and Overall/NS-AHI and Mador the best specificity.
Conclusions: The four criteria used to identify POSA have similarities and differences. While there were similarities between the Cartwright and Overall/NS-AHI criteria in the detection of POSA prevalence across both scoring criteria, the Overall/NS-AHI provided the most consistent detection of those most likely to demonstrate important reductions in sleep disordered breathing severity if supine sleep is avoided.

1. Introduction

Obstructive sleep apnea (OSA) treatment recommendations are typically based on the Apnea–Hypopnea Index (AHI) severity as well as the degree to which the clinician believes the patient will benefit from the therapy. For example, continuous positive airway pressure (CPAP) resolves OSA if the pressure and mask are properly selected and the patient uses it. Non-CPAP therapies, which are typically recommended for patients with mild or moderate OSA or those who do not or cannot use CPAP, generally provide a less efficacious and a more variable therapeutic response [1]. For patients with positional OSA (POSA), new-generation positional therapy (PT) devices (ie, vibrotactile feedback to the neck or chest) have potential, based on efficacy and improved compliance, compared to the traditional positional restraints (ie, using tennis balls) when used alone or potentially in combination with oral appliance therapy [2–5].

The proportion of patients with OSA who might benefit from PT is estimated to range from 56% to 75% depending on the severity of supine and nonsupine (NS) sleep-disordered breathing (SDB) and time spent in the supine position as well as age, ethnicity, the

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definition used to score hypopneas, and the criteria used to characterize POSA [2,3,6–8]. Cartwright was the first to fully characterize the influence of sleeping position on OSA severity, who defined patients with POSA as those who had a supine AHI at least twice that in the NS position [9]. Oksenberg et al., were the first to assess the prevalence and characteristics of patients with POSA [positional patients (PPs) and patients whose OSA was considered nonpositional (NPPs)], using the Cartwright definition, in a population of patients referred to a sleep unit [6]. Mador et al., suggested that those with POSA should meet the Cartwright criterion and must also have a NS AHI <5/h [10], whereas Marklund et al., selected a less rigorous NS criteria of AHI <10/h [11]. Bignold et al., was the first to combine a minimum amount of time (ie, 20 min) in the supine and NS positions with the Cartwright criterion plus a NS AHI <15/h to characterize POSA [12]. The Amsterdam POSA Classification (APOC) criterion was created to facilitate the identification of suitable candidates for PT. This approach provided a differentiation between what they called "true positional patients," that is, those who would be "cured" by avoiding supine sleep, and "true non-positional patients," those whose AHI was uninfluenced by position, as well as multifactorial patients whose OSA severity is influenced in part by the sleep position (including those diagnosed with severe overall OSA) [13,14]. In an effort to increase the likelihood that selected patients would achieve at least a 50% reduction in overall AHI if supine sleep was avoided, Levendowski et al., introduced the POSA definition whereby the overall AHI needed to be at least 1.5 times the NS severity (Overall/NS-AHI) [2].

In summary, Cartwright, Bignold, and Levendowski introduced POSA criteria, which attempted to detect those most likely to experience important reductions in overall OSA severity if supine sleep was avoided. Mador and Marklund applied a more strict definition by which PPs were essentially cured if they were adherent to PT. APOC attempted to achieve both objectives, ie, identify patients either who would be cured or who might obtain significant reductions in OSA severity if PT was successful. While Cartwright (without minimum supine and NS sleep time) is the most commonly referenced POSA criterion, none of these definitions have gained universal acceptance as the "standard" for the identification of patients who would likely benefit from PT. To further complicate matters, the comparative benefit of these POSA criteria is the impact changes in the American Academy of Sleep Medicine (AASM) 2007 vs. 2012 scoring rules had on OSA prevalence [8].

This study systematically compares four POSA criteria based on the AASM 2007 and 2012 guidelines for scoring abnormal breathing events. First, we explore differences in predicted POSA prevalence. Second, we investigate differences in the identification of POSA based on expected reductions in OSA severity with PT.

2. Methods

2.1. Data selection

A retrospective analysis of 242 unattended polysomnography (PSG) recordings consecutively acquired between November 1, 2016, and May 31, 2017, at a single clinical practice was approved by the Biomed IRB (San Diego, CA). To control variability between sleep and recording time, 27 records with recording time <5.5 h and two records with <2 h of sleep time were excluded. To be consistent with APOC criterion, 23 studies with supine time <10%, nine records with NS time <10%, and 20 records with an AHI <5% based on the AASM^{2012} hypopnea criteria were excluded. Nineteen records with no airflow for >15% of the night were excluded to control AHI variability resulting from excessive technician editing (ie, required extensive manual introduction of hypopneas). As a result, 96 records with an AHI^{2007} ≥5 and 142 records with an AHI^{2012} ≥5 were analyzed (see Table 3 for demographic data).

2.2. Data acquisition

Recordings were made using the Sleep Profiler-PSG2™ (Advanced Brain Monitoring, Carlsbad, CA, USA), a system that acquired the three channels electroencephalography, electrooculography, and electromyography activity from frontopolar sites; airflow using a nasal cannula and pressure transducer; head movement/position by actigraphy; snoring with an acoustic microphone; pulse from the forehead and finger; wireless wrist oximetry; and thorax and abdomen effort by respiratory induced plethysmography. Before sending the patient home with the device, the effort belts and headband were adjusted by the technician while subjects watched an instructional video. Subjects then practiced applying the Sleep Profiler-PSG2 before taking it home with instructions to wear it for a minimum of 8 h. When the device was turned on, voice messages assisted the subjects to ensure that all of the sensors were properly applied. During the night, voice messages were delivered whenever the oximeter finger probe fell off or up to four times per night when the cannula was not properly seated in the nares.

2.3. Scoring

The recordings were uploaded to the Sleep Profiler portal where automated algorithms were applied to the signals. For this study, AHI^{2007} was based on the AASM 2007 scoring rules requiring hypopneas to be confirmed with a minimum of 4% desaturation, whereas the AHI^{2012} was based on the AASM 2012 rules requiring hypopneas to be confirmed with either a 3% desaturation or a cortical arousal [15]. Auto-staging was performed using previously described techniques that relied on the ratios of the power spectral densities and autodetection of cortical and microarousals, sleep spindles, and ocular activity [16]. The airflow signal was analyzed using automated algorithms that detect apneas based on a 90% reduction in airflow and hypopneas based on a 30% reduction of flow volume. The SpO_2 signal was analyzed to detect both 3% and 4% desaturations, which were combined with the airflow signal for detection of hypopneas. After the studies were processed, an independent focused review of the home full disclosure recordings was conducted by the same technician to confirm accuracy of the auto-sleep staging and auto-detection of apnea/hypopnea events [17,18].

2.4. Data analysis

The four POSA criteria used in this study are summarized in Table 1. The inclusion criteria satisfied the APOC criterion for an

Table 1
Summary comparison of the POSA criteria.

	Supine/NS AHI	Min Nonsupine AHI	Change in AHI severity	% Time Supine and NS	Overall/NS AHI
APOC		APOC I < 5	APOC II and III	≥10%	
Cartwright	≥2.0				
Mador	≥2.0	<5			
Overall/NS-AHI				≥20 m	≥1.4

Table 2
Comparison of POSA criteria for two hypothetical cases with moderate OSA achieved with different combinations of supine AHI and the % time supine.

Supine AHI	NS AHI	% Time supine	Overall	Cartwright ratio	Overall/NS ratio	Classified as POSA				Reduction in AHI
			AHI			APOC	Cartwright	Mador	Overall/NS	
35	14	10%	16	2.5	1.15	Yes	Yes	No	No	13%
35	11	20%	16	3.2	1.44	Yes	Yes	No	Yes	31%
25	16	55%	21	1.6	1.31	No	No	No	No	24%
25	13	70%	21	1.9	1.65	Yes	No	No	Yes	38%

overall severity ≥5 with more than 10% of total sleep time (TST) in both best sleeping position (BSP) and worst sleeping position (WSP). The characterization of POSA by APOC criteria additionally required one of three rules to be satisfied. The APOC-I rule required the BSP AHI to be less than five. APOC-II required the BSP severity to fall in a lower AHI severity category than the overall AHI. APOC-III required the AHI in the BSP to be at least 25% lower than the overall AHI in those with an overall AHI ≥40. The Cartwright criterion required the supine AHI to be at least two times greater than the NS AHI. The Mador criterion applied the Cartwright rule with the additional requirement that the NS AHI must be <5. The Overall/NS-AHI criterion applied in this study required the overall AHI to be at least 1.4 times the NS AHI and at least 20 min in both supine and NS sleep positions.

Pearson correlations were used to evaluate the relationships between Cartwright vs. Overall/NS-AHI ratios, the two criteria that provided continuous measures reflecting the impact supine sleep had on the overall OSA severity. To minimize the influence of outliers on the correlation analysis, AHI between 0 and 1 were assigned a value of one before computing the Cartwright and Overall/NS-AHI ratios.

Conventional clinical cutoffs for mild (AHI 5–14), moderate (AHI 15–29), and severe (AHI ≥30) OSA were applied. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the four POSA criteria were computed by comparing these values with the four reference standards, ie, the overall AHI would decrease by 25%, 35%, 50%, or 75% if the BSP was maintained for the entire night. The 25% reference standard was selected as the minimum clinical threshold because it was recognized by the APOC criterion as a potentially important change in overall AHI that may benefit patients with POSA. The 50% reduction in overall AHI has been conventionally used as a minimum response criterion to an OSA therapeutic intervention. The 35% and 75% thresholds were included for a broader compare/contrast analysis.

Receiver operating characteristic curves (ROCs) were generated for all criteria by the AASM scoring method applying clinical cutoffs (ie, minimum AHI percent improvement) ranging from 10% to 90%. Two-tailed, Fisher exact, and chi-square analyses were used to evaluate significant changes in the distributions of overall POSA by and across POSA criteria and AHI^{2007} and AHI^{2012} scoring rules.

Table 2 presents four hypothetical cases to demonstrate differences in the POSA criteria, classifications resulting from different combinations of supine severity and supine time when the overall AHI severity is moderate. False-positive and false-negative findings are dependent on the POSA classification and the expected percent reduction in overall AHI. In the first example, a POSA classification of "yes" would result in a false-positive result based on a 13% reduction in overall AHI when compared to a 25% reference value.

Table 3
Demographic and sleep data for the 142 subjects.

	Mean (SD)
Age (years)	44.5 ± 13.5
Gender (females, males)	73, 69
Body mass index (kg/m^2)	31.7 ± 7.2
Neck size (cm)	40.0 ± 3.2
Epworth Sleepiness Scores	8.4 ± 4.8
Insomnia Severity Index	13.2 ± 5.5
Sleep time (h)	6.4 ± 1.3
Percent sleep time supine (%)	38.1 ± 20.5
AHI^{2007} (events/h)	17.3 ± 21.6
Supine AHI^{2007} (events/h)	28.0 ± 27.4
Nonsupine AHI^{2007} (events/h)	10.9 ± 18.6
AHI^{2012} (events/h)	28.0 ± 24.2
Supine AHI^{2012} (events/h)	43.6 ± 31.5
Nonsupine AHI^{2012} (events/h)	18.9 ± 21.1

3. Results

3.1. Association between continuous estimates of POSA severity

The concordance between the Cartwright and Overall/NS-AHI ratios strengthened from 0.79 to 0.87 with the AHI^{2012} scoring rules because of greater number of detected hypopnea events (see Fig. 1).

3.2. POSA prevalence

Table 4 presents the predicted prevalence of patients with POSA by criteria in records with ≥5 events/h by and across OSA severities. The change in scoring rules from AHI^{2007} to AHI^{2012} increased the number of patients identified with at least mild SDB by approximately 50% (ie, 96 vs. 142). APOC, Cartwright, and overall/NS-AHI identified similar percentages of patients with overall POSA based on AHI^{2007}. Looking across the scoring rules, the proportion of those characterized with POSA remained similar for the Cartwright and the Overall/NS-AHI criteria, whereas APOC identified 16% less prevalence of POSA on the basis of AHI^{2012} rules vs. AHI^{2007} ($p < 0.05$). Mador identified significantly less POSA compared to the other criteria ($p < 0.01$) for both AHI^{2007} and AHI^{2012}. The proportion of patients identified with moderate and severe POSA by APOC, Cartwright, and Overall/NS-AHI criteria for both AHI^{2007} and AHI^{2012} was similar. The POSA prevalence for APOC I, II, and III was 39%, 21%, and 7%, respectively, for AHI^{2007} and 22%, 23%, and 6%, respectively, for AHI^{2012}. Of the 46 patients with an AHI^{2007}<5 and an AHI^{2012}≥5, only 52% were classified as APOC I.

3.3. Detecting the influence of supine sleep on overall OSA severity

The sensitivities and specificities computed for reference standards ranging from 10% to 90% (ie, expected reductions in overall AHI if supine sleep is avoided) were used to compute ROCs presented in Fig. 2. For the AHI^{2007}, the areas under the curve were Overall/NS-AHI = 1.0, Cartwright = 0.99, Mador = 0.95, and APOC = 0.91 (Fig. 2a). For the AHI^{2012}, the areas under the curve for Overall/NS-AHI, Cartwright, Mador, and APOC were 1.00, 0.97, 0.92, and 0.86, respectively (Fig. 2b).

Table 5 highlights the differences in POSA criteria performance with regard to identifying those who would be expected to achieve a 25%, 35%, 50%, and 75% reduction in overall severity if the

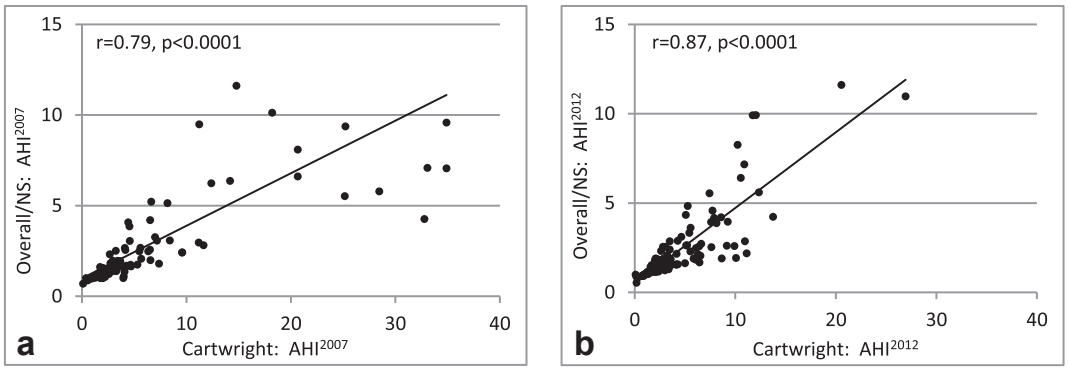

Fig. 1. Scatter plot of the ratios obtained from the supine divided by the nonsupine severity (Cartwright) and the overall AHI divided by nonsupine severity (Overall/NS-AHI) for (a) AHI^{2007} and (b) AHI^{2012}.

proportion of supine sleep found on the diagnostic recording was avoided.

The APOC, Cartwright, and Overall/NS criteria exhibited relatively high sensitivity and NPV combined with a gradual decline in specificity and PPV as the reference values increased. Conversely, Mador showed a relatively high and stable specificity and PPV, with gradual increase in sensitivity and NPV as the reference values increased. When a 25% or 35% reduction in overall AHI was targeted, the Overall/NS-AHI criterion provided the greatest number of accuracy measures above 0.85.

4. Discussion

The impact of the AASM scoring rules on the prevalence of POSA was highly dependent on the POSA criteria. Although the number of PPs increased by 50% as a result of the new definition of hypopneas, POSA prevalence was approximately 60% by Cartwright and Overall/NS-AHI criteria in patients with at least mild OSA by both AHI^{2007} and AHI^{2012}. Conversely, a 16% decline in POSA prevalence for AHI^{2012} was observed with the Mador and APOC criteria resulting from fewer patients being identified with a NS AHI <5 (ie, no longer satisfied Mador or APOC-I) and/or the BSP and WSP AHI being ≥5 and < 15 events/h; hence, APOC II was not satisfied.

In addition to the ROC plots, a range of reference standards was selected to assess differences in the capability of the POSA criteria to identify those who would likely achieve substantial reductions in SDB if the supine position was avoided. The Overall/NS-AHI was superior in identifying those who would likely achieve important reductions in their overall AHI with supine avoidance, with near-perfect accuracy at the reference value of 25% and substantially stronger area under the curve (Fig. 2). Virtually all of the presumed "false-positive" classifications at reference values of 35%, 50%, and 75% still reported at least a 25% reduction in overall AHI^{2012}. In contrast, 25% of the Cartwright false-positive cases, 40% of the APOC false-positive cases, and 70% of the Mador false-positive cases resulted in overall AHI reductions <25% assuming supine sleep was avoided. While the vast majority of the Cartwright misclassification was false-positive cases, the APOC criterion generated both type I and II errors. The Mador criterion proved specific but because it required NS AHI <5 (ie, similar to what might be obtained with CPAP if adherence was optimal), it was insensitive to the identification of many patients who might benefit from PT.

Although PT is generally recommended only for those with mild and moderate OSA, the APOC, Cartwright, and Overall/NS-AHI found that a similar proportion of those with moderate and severe OSA was strongly influenced by sleeping position. While it is unlikely that the NS AHI^{2012} will resolve into the normal range for those with severe POSA, further studies are needed to evaluate the degree to which patients with severe POSA who fail or refuse CPAP benefit from PT, or PT in combination with oral appliance therapy.

The four POSA criteria that evaluated the characterization of POSA were selected because each could be applied to all records (ie, the Marklund criterion would have required records with a BSP AHI between 5 and 10 to be excluded). The Mador criterion is considered a stricter definition of POSA because it identifies those patients who would be cured if they avoid the supine position. The APOC criterion expanded the definition of POSA to include those patients with OSA disproportionately impacted by supine sleep, arguing that these patients would improve with the use of PT and/or might benefit from PT in combination with other OSA therapies. The Cartwright and the Overall/NS-AHI criteria, on the other hand, are easy to compute ratios that provide continuous measures reflecting the impact supine sleep had on the overall OSA severity. The minimum 10% of TST in both the BSP and WSP, a requirement of APOC, reduced the number of false-positive assignments made by the Cartwright ratio when very short supine or NS sleep times were encountered. This approach would still result in an incorrect assignment of POSA because of an insufficient allocation of diagnostic time across both BSP and WSP, a common occurrence in split-night PSG studies. While the concordance between Overall/NS-AHI and Cartwright criteria was high, the performance of the Cartwright criterion benefitted from elimination of studies with less than 10% of sleep time in the BSP and WSP. The Overall/NS-AHI

Table 4
The distribution of POSA by criteria and AHI severity for records with AHI ≥ 5 events/hour.

POSA criterion	AHI^{2007}				AHI^{2012}			
	Overall	Mild	Mod.	Severe	Overall	Mild	Mod.	Severe
APOC, % (n)	66.7 (64)	30.2 (29)	19.8 (19)	16.7 (16)	50.7 (72)	16.9 (24)	15.5 (22)	18.3 (26)
Cartwright, % (n)	68.7 (66)	33.3 (32)	19.8 (19)	15.6 (15)	64.8 (92)	26.8 (38)	20.4 (29)	17.6 (25)
Mador, % (n)	36.4 (35)	28.1 (27)	7.3 (7)	1.0 (1)	19.7 (28)	14.8 (21)	4.2 (6)	.7 (1)
Overall/NS-AHI, % (n)	63.5 (61)	31.2 (30)	17.7 (17)	14.6 (14)	58.4 (83)	23.2 (33)	19.7 (28)	15.5 (22)
SDB ≥ 5, % (n)	100.0 (96)	45.8 (44)	26.1 (25)	28.1 (27)	100.0 (142)	42.2 (60)	26.8 (38)	31.0 (44)

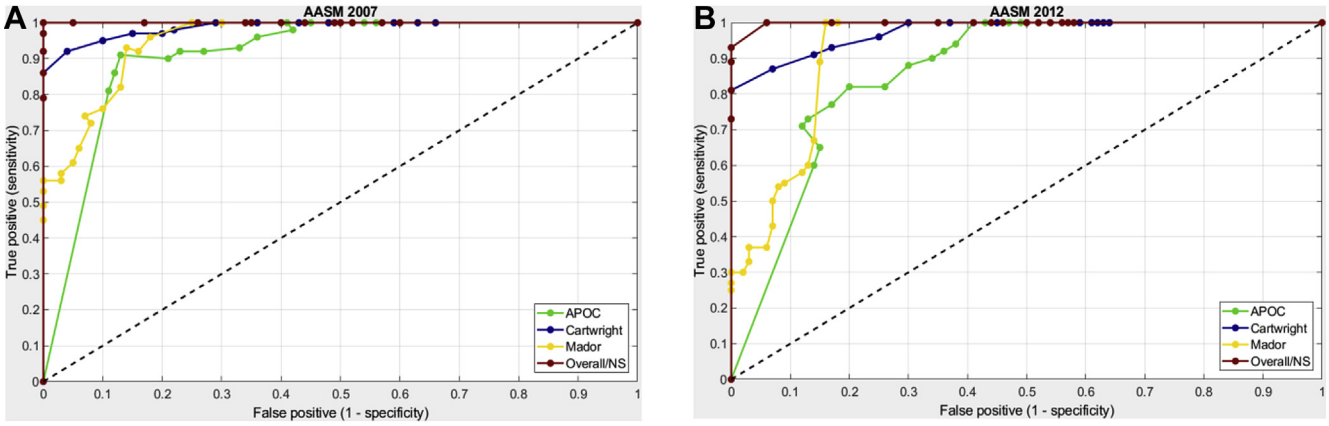

Fig. 2. Receiver operating characteristic curves based on reference standards ranging from 10% to 90% improvement in overall AHI (assuming supine sleep is avoided) for the four criteria of (a) AHI^{2007} and (b) AHI^{2012}.

criterion, on the other hand, incorporates positional sleep time into the POSA criterion because the overall AHI cannot mathematically exceed the NS severity by 1.4 without appropriate combinations of severity and/or minimum amount of time (ie, approximately 20 min) in the BSP and WSP. This 20-min window is equivalent to the 10% minimum proposed by APOC when TST exceeds 3.3 h. The results from this study support the change to a POSA criterion that readily and accurately incorporates the impact of both supine severity and supine sleep time in the identification of patients with POSA who might benefit from supine sleep avoidance.

The assumption that POSA can be predicted by Overall/NS-AHI and that the AHI would be effectively reduced when supine sleep is avoided was prospectively demonstrated in a four week evaluation of vibrotactile PT [2]. In this study of 30 patients, the Overall/NS-AHI criterion was applied to the diagnostic PSG-AHI^{2007} (minimum 4 h of PSG-TST) with sleeping position measured at the torso. Ninety percent of these PPs showed at least a 35% reduction in total AHI and the median reduction was 79% when supine sleep was restricted. We subsequently reported that after 30 days of PT therapy, the diagnostic NS AHI was stable within five events/h in 67% of the patients, decreased in 20%, and increased in 13% of the cases [19]. These findings suggest the Overall/NS-AHI criterion may reasonably estimate a treatment response to the new-generation PT devices in more than 85% of patients. In the FDA submission study, an Overall/NS-AHI threshold of 1.5 was used because it was imperative that enrolled patients would achieve at least a 50% reduction in the overall AHI if the PT was effective. An Overall/NS-AHI threshold of 1.4 was selected for this study because it provided a more balanced sensitivity and specificity distribution. A shift in the Overall/NS-AHI criterion clinical cutoff to a higher value simply increases the minimum required supine sleep time and/or severity.

One limitation of this study is that the criteria comparisons were not made using conventional laboratory PSG. In a previous report comparing the auto-scoring to simultaneously recorded, manually scored laboratory PSG, the sensitivities and specificities using clinical cutoffs of overall AHI^{2007} $\geq$5 and $\geq$10 events/h were 0.98 vs. 0.85 and 0.94 vs. 0.96, respectively [17]. Given the accuracy of frontopolar EEG in the detection of sleep time was 87% vs. PSG [16], and the airflow algorithm was applied in both AHI^{2007} and AHI^{2012}, differences in hypopnea recognition in this study were limited to the automated detection of desaturations and/or auto-scored arousals.

Another limitation was that sleeping position was measured from the forehead rather than the conventional approach of measuring the torso/body position during PSG. When compared to

Table 5
Detection accuracies for each POSA criteria across range of reference values from 25% to 75% for the two AHI measures.

Detection accuracy	AHI^{2007}				AHI^{2012}			
	25%	35%	50%	75%	25%	35%	50%	75%
Sensitivity								
APOC	0.90	0.92	0.98	1.00	0.73	0.82	0.90	1.00
Cartwright	0.97	0.97	1.00	1.00	0.93	1.00	1.00	1.00
Mador	0.56	0.58	0.72	0.92	0.30	0.37	0.50	0.67
Overall/NS-AHI	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
Specificity								
APOC	0.79	0.73	0.58	0.46	0.87	0.80	0.66	0.55
Cartwright	0.85	0.78	0.58	0.43	0.83	0.70	0.50	0.39
Mador	1.00	0.97	0.92	0.84	0.98	0.97	0.93	0.86
Overall/NS-AHI	1.00	0.95	0.66	0.50	1.00	0.83	0.59	0.46
Positive predictive value (PPV)								
APOC	0.89	0.84	0.66	0.41	0.90	0.81	0.53	0.21
Cartwright	0.92	0.88	0.66	0.39	0.90	0.77	0.46	0.16
Mador	1.00	0.97	0.89	0.69	0.96	0.93	0.75	0.36
Overall/NS-AHI	1.00	0.97	0.70	0.43	1.00	0.86	0.51	0.18
Negative predictive value (NVP)								
APOC	0.81	0.84	0.97	1.00	0.66	0.81	0.94	1.00
Cartwright	0.93	0.94	1.00	1.00	0.88	1.00	1.00	1.00
Mador	0.54	0.59	0.80	0.97	0.46	0.61	0.82	0.96
Overall/NS-AHI	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00

PSG and body position, head position plus auto-scored SDB events provided supine sensitivities and specificities of 0.93 vs. 0.72 and 0.96 vs. 0.90, respectively, for AHI^{2007} ≥5 and ≥10 [17].

If the measurement of head vs. body position, or the use of in-home rather than laboratory PSG resulted in a significant measurement bias, it is unlikely that the POSA prevalence based on the Cartwright criterion in this study would have been similar to the prevalence observed using laboratory PSG-based AHI^{2007} (ie, 69% vs. 64%, respectively) [13]. Additionally, the distributions of head position-based APOC 1, 2, and 3 for AHI^{2007} in this study were very similar to those reported by Ravesloot et al., based on PSG and body position [14]. Furthermore, the overall AHI^{2012}A-POC-based POSA prevalence in this study was similar to that reported by Duce (ie, 51% vs. 49%) [20]. There were differences between the APOC distributions in this study vs. Duce study, but similar to what was reported when comparing to Ravesloot et al., study, Duce and colleagues reported that 14% of their cohort satisfied AHI^{2007}APOC II or III criteria, whereas Ravesloot and the present study reported 32% and 28%, respectively. Consistent with the AHI^{2007} results, 29% of our cohort satisfied AHI^{2012}APOC II or III criteria vs. 9% for Duce et al. These results suggest that the reported differences in POSA prevalence and criteria accuracy were reasonably estimated.

While the likelihood that the sources of differences in POSA prevalence and criteria accuracy were reasonably estimated, this study points to a number of research applications that could be explored. First, this study should be repeated using manual scoring by the two guidelines to confirm the reported differences in POSA criteria. Investigations are needed to evaluate the minimum sleep time needed to characterize POSA considering the influence of REM sleep. Moreover, studies are needed to confirm these results and demonstrate generalization of the Overall/NS-AHI criterion using different position sensors and from different body locations [2,17,21–23]. Because recordings were made for only one night, further studies are needed to determine whether the detection accuracy obtained with the Overall/NS-AHI criterion is impacted by night-to-night variability in OSA severity and sleeping position [24,25]. Strong evidence has demonstrated that the new-generation PT devices are effective in reducing the AHI in the short term, and because these devices can monitor PT compliance, evidence of long-term effectiveness is increasing [3,5,26,27]. Finally, future investigations are also needed to determine whether POSA characteristic and/or criterion can be used to identify those who are more likely to be long-term compliant with these new-generation PT devices [28,29].

This study provided a systematic comparison of methods that characterize POSA in an effort to improve the identification of those who would likely benefit from PT. The application of any threshold-based POSA-detecting criteria is somewhat artificial as compared to a trial that included a full range of snorers all the way up to those with the most severe OSA and results in defining characteristics that allow clinicians to give accurate advice about the chance of therapeutic success. A PT trial, like CPAP, requires an allocation of resources; thus, it would be preferable to identify a priori those most likely to benefit from the therapy. It could also be argued that because clinicians are trained to interpret diagnostic studies and make treatment recommendations for OSA using threshold-based severity criteria, simple rules or guidelines that fit into that model are needed for a PT trial to be considered. Reliable identification of those with moderate and severe position-influenced OSA is needed for expanded use of PT in combination with other therapies. Finally, phenotype characterization that increase the odds of PT response is needed in the design of cost-effective healthcare coverage policies that optimize patient access to care.

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Conflicts of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2018.05.012.

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