http://dx.doi.org/10.5665/sleep.1710

AASM Criteria for Scoring Respiratory Events: Interaction between Apnea Sensor and Hypopnea Definition

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Study Objectives: To examine the impact of using a nasal pressure sensor only vs the American Academy of Sleep Medicine (AASM) recommended combination of thermal and nasal pressure sensors on (1) the apnea index (AI), (2) the apnea-hypopnea index (AHI), where the AHI is calculated using both AASM definitions of hypopnea, and (3) the accuracy of a diagnosis of obstructive sleep apnea (OSA).

Design: Retrospective review of previously scored in-laboratory polysomnography.

Setting: A tertiary-hospital clinical sleep laboratory.

Patients or Participants: One hundred sixty-four consecutive adult patients with a potential diagnosis of OSA, who were examined during a 3-month period.

Interventions: N/A.

Measurements and Results: Studies were scored with and without the use of the oronasal thermal sensor. AIs and AHIs, using the nasal pressure sensor alone (AI_{np} and AHI_{np}), were compared with those using both a thermal sensor for the detection of apnea and a nasal pressure transducer for the detection of hypopnea (AI_{th} and AHI_{th}). Comparisons were repeated using the AASM recommended ($AASM_{rec}$) and alternative ($AASM_{alt}$) hypopnea definitions. AI was significantly different when measured from the different sensors, with AI_{np} being 51% higher on average. Using the $AASM_{rec}$ hypopnea definition, the mean AHI_{np} was 15% larger than the AHI_{th}; with large interindividual differences and an estimated 9.8% of patients having a false-positive OSA diagnosis at a cutpoint of 15 events and 4.3% at 30 events per hour. Using $AASM_{alt}$ hypopnea definition, the mean AHI_{np} was 3% larger than the AHI_{th}, with estimated false-positive rates of 4.6% and 2.4%, respectively. The false-negative rate was negligible at 0.1% for both hypopnea definitions.

Conclusions: This study demonstrates that using only a nasal pressure sensor for the detection of apnea resulted in higher values of AI and AHI than when the AASM recommended thermal sensor was added to detect apnea. When the $AASM_{alt}$ hypopnea definition was used, the differences in AHI and subsequent OSA diagnosis were small and less than when the $AASM_{rec}$ hypopnea definition was used. In situations in which a thermal sensor cannot be used, for example, in limited-channel diagnostic devices, the AHI obtained with a nasal pressure sensor alone differs less from the AHI obtained from a polysomnogram that includes a thermal sensor when the $AASM_{alt}$ definition rather than the $AASM_{rec}$ definition of hypopnea is used. Thus, diagnostic accuracy is impacted both by the absence of the thermal sensor and by the rules used to analyze the polysomnography. Furthermore, where the thermal sensor is unreliable for sections of a study, it is likely that use of the nasal pressure signal to detect apnea will have modest impact.

Keywords: AASM guidelines, thermal sensor, nasal pressure sensor, hypopnea, apnea, obstructive sleep apnea, sleep disordered breathing, polysomnography, methodology, scoring, diagnosis

Citation: Thornton AT; Singh P; Ruehland WR; Rochford PD. AASM criteria for scoring respiratory events: interaction between apnea sensor and hypopnea definition. *SLEEP* 2012;35(3):425-432.

INTRODUCTION

In 2007, the American Academy of Sleep Medicine (AASM) published the Manual for the Scoring of Sleep and Associated Events.[1] Following the publication of the manual, there have been a number of criticisms[2-7]; the major criticism has been the endorsement by the AASM of 2 quite disparate definitions of hypopnea.[6,7] Quantification of respiratory events is critical to the diagnosis of sleep apnea, with the apnea-hypopnea index (AHI) being the primary metric for determination of abnormality and severity; the 2 definitions have been shown to result in substantial differences in AHI.[6,8]

The AASM manual also clarified the definition of apnea, providing rules for measuring event duration, the extent of airflow reduction and the sensor to be used for apnea detection. The guidelines require that "the sensor to detect absence of airflow for identification of an apnea is an oronasal thermal sensor."[1] The alternative sensor for apnea detection, and the AASM recommended sensor for hypopnea detection, is nasal pressure. These recommendations supercede those in the AASM consensus report of 1999, also known as "Chicago Criteria,"[9] which had emphasized nasal pressure as a semi-quantitative measure of airflow and recommended against the routine use of thermal sensors.

Despite the AASM recommendations, there is no direct evidence to support the need for both sensors. Nasal-pressure sensors are less sensitive to low levels of flow[10,11] and will not detect oral airflow; hence, it may be that some apneas scored by nasal pressure would be scored as hypopneas with the addition of thermal sensors. It might also follow that there will be little or no net effect on the AHI but simply a shift between event categories—from apnea to hypopnea. On the other hand, because the apnea definition does not require an associated oxygen desaturation or cortical arousal, it is at least possible that apneas scored with nasal pressure alone would not qualify as an apnea *or* hypnopea with the addition of a thermal sensor, resulting in a reduction in the AHI.

Submitted for publication April, 2011
Submitted in final revised form August, 2011
Accepted for publication October, 2011

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This study was undertaken to examine differences in the apnea index (AI) and AHI as a result of the use of different sensors in a typical population referred to an adult sleep laboratory for the evaluation of obstructive sleep apnea (OSA). It is novel in that it examines the impact on the AHI using both the AASM recommended hypopnea definition ($AASM_{rec}$) and the AASM alternative definition ($AASM_{alt}$).

The potential value of the study is fourfold. Firstly, there is an advantage in reducing the number of sensors used in polysomnography to increase patient comfort and decrease the complexity of the procedure. Secondly, where reduced montages are used, such as in Type III or Type IV limited diagnostic devices,[12,13] there may be no capacity to include both types of sensor; therefore, this study may provide information about the agreement in AHI and diagnostic accuracy when these studies are compared with full polysomnography. Thirdly, it provides the opportunity to examine the AASM recommendation that nasal pressure should be used as the alternative sensor for apnea detection when the oronasal thermal sensor is not reliable.[1] Fourthly, it provides information on the impact on AHI measurement of moving from Chicago to AASM measurement standards.

In summary, this study addresses the question of whether the use of the oronasal thermal sensor in addition to nasal pressure has an impact on respiratory-event detection, classification, and diagnostic accuracy and whether both sensors are essential to produce results that match AASM guidelines or whether the nasal pressure transducer alone could be used to detect apnea.

METHODS

Patient Selection

This study used a sample of 164 consecutive diagnostic in-laboratory polysomnograms recorded during a 3-month period in 2007 at the Royal Adelaide Hospital sleep laboratory in Adelaide, South Australia. All patients were being investigated for clinically suspected OSA or exclusion of OSA. As signal quality was likely to be an important factor in the comparison of the 2 sensors and to maximize generalizability, no polysomnograms were excluded based on poor-quality nasal pressure or oronasal thermal sensor signals. Polysomnograms were excluded if other key signals (oxygen saturation [SaO_2] or electroencephalogram [EEG]) were uninterpretable for at least 50% of sleep time.

Polysomnography Recordings

Polysomnograms were recorded using Compumedics E-series equipment (Compumedics Ltd, Abbotsford, Victoria, Australia) using a recording montage consisting of C3/M2 EEG, left and right electrooculogram, electrocardiogram, submental electromyogram, airflow from nasal pressure transducer and oronasal thermocouple (Compumedics Ltd), body position, thoracic and abdominal excursion (inductance plethysmography), finger pulse oximetry using a MasimoSET Radical (Masimo, Irvine, CA) set to an averaging time of 8 seconds and sampled at 1 Hz, left and right leg movement (piezoelectric sensors), and sound from a sound pressure meter (RION Co. Ltd, Tokyo, Japan).

Recordings were made as part of a routine diagnostic service, reflecting common laboratory practices. Overnight staff were instructed to correct respiratory sensors that were not functioning correctly when the patient awoke but made no other special efforts to maximize signal integrity.

Polysomnography Scoring

Polysomnograms were first scored using Compumedics Profusion PSG 2 software by 1 of 3 scorers, all of whom participated in intra- and interlaboratory scoring concordance programs.[14] Scoring was based on Rechtschaffen and Kales rules for sleep[15] and American Sleep Disorders Association rules for arousal scoring.[16] Respiratory events were initially identified using "Chicago" criteria[9] with nasal pressure used to determine apnea and hypopnea. The Chicago criteria define obstructive apnea or hypopnea as a complete cessation or 50% reduction in a valid measure of airflow or a clear reduction in airflow accompanied by arousal from sleep or a 3% oxygen desaturation. The AASM hypopnea criteria require a 30% reduction in airflow accompanied by a 4% oxygen desaturation ($AASM_{rec}$) or a 50% reduction in airflow accompanied by a 3% oxygen desaturation or arousal ($AASM_{alt}$).[1] Consequently, Chicago criteria effectively incorporate events that would meet both $AASM_{rec}$ and $AASM_{alt}$ criteria. A single investigator (PS) retrospectively reviewed the polysomnograms and rescored events according to the flowchart in Figure 1.

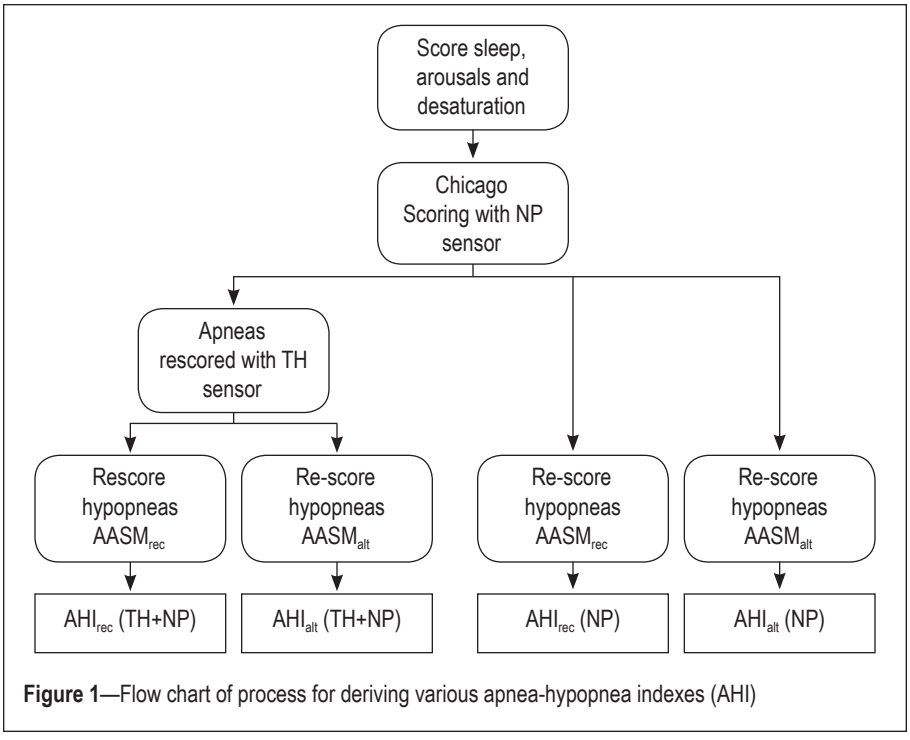

Figure 1—Flow chart of process for deriving various apnea-hypopnea indexes (AHI)

Where the signal being considered—the thermal sensor or the nasal pressure sensor—was of inadequate quality to score events, the inductive plethysmography signal from chest and abdomen was used to score events. Importantly, to avoid confounding the data, if the thermal sensor

was inadequate, the nasal pressure sensor was *not* used to score events and *vice versa*.

Analysis and Statistics

The distribution of AIs and AHIs and of the differences between each pair of AHIs was skewed, and, therefore, nonparametric analyses were undertaken. Variables were described according to their median and interquartile values. For comparison with published values, the mean and standard deviation were also calculated. The significance of differences in AIs and AHIs was examined using the Wilcoxon signed-rank test. Scatter plots and Bland-Altman plots[17] were constructed for inspection of the association and agreement between AIs and AHIs. The strength of association was determined with Spearman rank test. From the Bland-Altman plots, agreement was reported as the median difference (bias) between scoring criteria and the fifth and 95th percentiles of the difference.

With the AASM recommended scoring montage of thermal sensor and nasal pressure sensor as the gold standard, the sensitivity and specificity of the nasal pressure transducer alone to diagnose OSA was defined for both recommended and alternative hypopnea definitions. False positive and false negative rates throughout the range of 5 to 60 events per hour were calculated. The significance of differences of false positive and false negative rates between the corresponding indices was examined using the Wilcoxon signed-rank test. To provide a smoothed estimate of the false positive rate at conventional cutpoints of 5, 15, and 30 per hour, the false positive rate was modeled as a function of AHI using a least-squares best-fit exponential, which asymptotically approached 0 at high AHI.

RESULTS

Patient Characteristics

Table 1 summarizes the patient characteristics and polysomnography results.

Signal Quality

The thermal sensor was judged to be of inadequate quality for scoring in more than 20% of epochs of 12 studies (7%), and the nasal pressure was inadequate in 4 studies (2.5%). All studies were included in the analysis to mirror a real-life situation.

Agreement Between Scoring Criteria

Table 2 shows median and mean AHI and AI according to apnea sensor and hypopnea scoring criterion. The Wilcoxon signed- rank test revealed that all AHIs were significantly different from each other ($P < 0.001$) and that the AI scored from nasal pressure tracing (AI_{np}) was different from the AI scored from oronasal thermal sensor (AI_{th}) ($P < 0.0001$).

Scatter plots (Figure 2) and Bland-Altman plots (Figure 3) were constructed for the inspection of association and agreement between AI_{np} (using nasal pressure only) and AI_{th} (using AASM recommended montage of oronasal thermal and nasal pressure sensor). Similar plots were constructed for AHI_{np} and AHI_{th} for both AASM hypopnea definitions. They demonstrated large patient-specific differences, most importantly in AI and AHI_{rec}. For AI, 27 patients (16%) had a difference of more than 10 events per hour; for AHI_{rec}, 11 patients (7%), and for AHI_{alt}, 5 patients (3%). The strongest correlation and closest agreement was observed between AHI_{np} and AHI_{th} when the AASM alternative hypopnea definition was used.

The Bland-Altman plots demonstrate a median (5th, 95th percentile) increase of 1.6 per hour (0.0, 22.2) when comparing AI_{np} with AI_{th}, a median increase of 0.9 per hour (0.0, 10.7) when comparing AHI_{np} with AHI_{th} using the AASM recommended hypopnea definition, and a median increase of 0.5 per

Table 1—Summary of patient characteristics and polysomnography results

Parameter	Value
No.	164
Age, y	50 (39, 60)
Males, no.	108
BMI, kg/m^2	33.0 (29.1, 37.8)[a]
ESS score	8 (6, 13)[b]
TST, min	337 (302, 377)
Sleep efficiency, %	78.0 (69.0, 85.2)
Sleep stage, min	
1	13.8 (9.6, 20.1)
2	190.0 (165.8, 216.3)
SWS	70.2 (40.2, 92.6)
REM	57.8 (38.6, 70.4)
Arl, events/h	20.7 (14.5, 35.3)
AHI, events/h[c]	11.5 (4.0, 30.7)

Values are shown as median (interquartile range) or number. BMI, body mass index; ESS, Epworth Sleepiness Scale; TST, total sleep time; SWS, slow wave sleep; REM, rapid eye movement; Arl, arousal index. [a]n = 163, [b]n = 161, [c]AHI (apnea-hypopnea index) is based on the $AASM_{alt}$ hypopnea definition using thermal and oronasal sensors.

Table 2—AHI and AI for different sensors and hypopnea scoring criteria

Apnea sensor	Hypopnea definition	Median AI[a]	Mean AI[b]	Median AHI[a]	Mean AHI[b]
Thermal	Recommended	2.1 (0.5, 9.4)	10.3 ± 18.4	6.7 (1.4, 21.0)	16.9 ± 23.2
	Alternative	2.1 (0.5, 9.4)	10.3 ± 18.4	11.5 (4.0, 30.7)	22.1 ± 25.0
Nasal pressure	Recommended	6.1 (1.0, 15.9)	15.6 ± 22.7	9.2 (2.2, 26.4)	19.5 ± 24.4
	Alternative	6.1 (1.0, 15.9)	15.6 ± 22.7	13.0 (4.0, 33.1)	23.5 ± 25.8

AHI, apnea-hypopnea index; AI, apnea index. [a]Values are shown as median (interquartile range)/h. $P < 0.001$ for all pair-wise comparisons of thermal vs pressure sensors. [b]Values are shown as mean (± SD)/h.

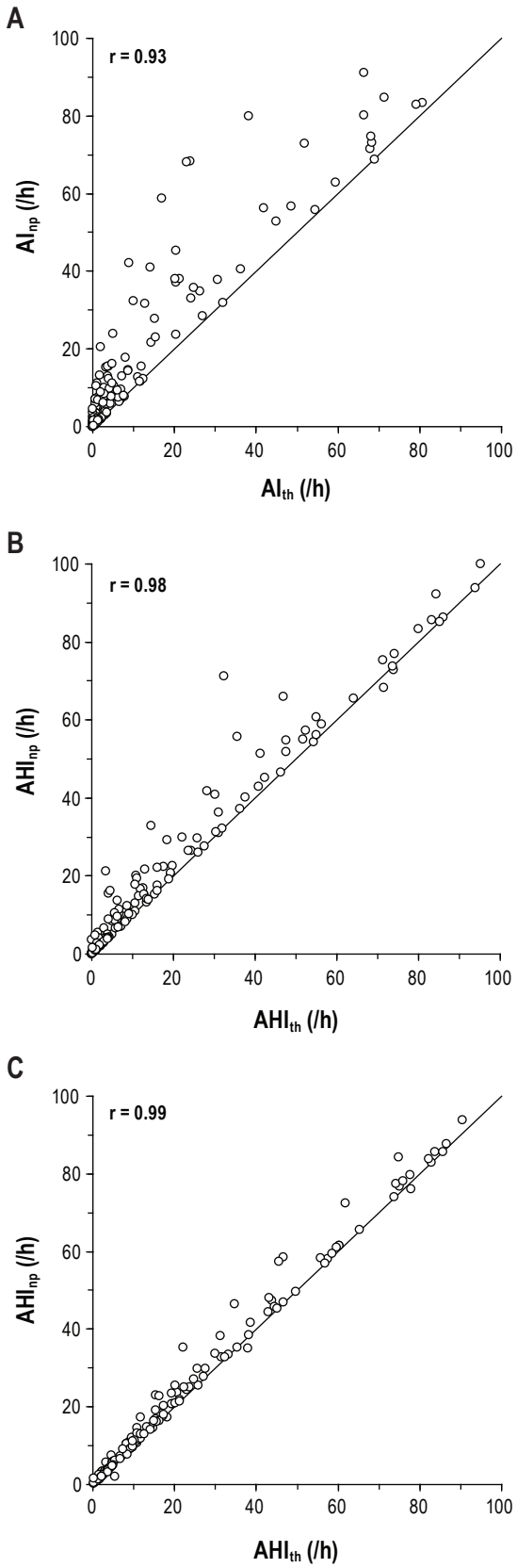

Figure 2—Scatter plots comparing: **(A)** AI_{np} (the apnea index, i.e., the total number of apneic events during the sleep time divided by the number of hours of sleep, obtained using the nasal pressure sensor) with the AI_{th}, **(B)** AHI_{np} to AHI_{th} using the AASM recommended definition and **(C)** AHI_{np} to AHI_{th} using the AASM alternative definition. The line is line of identity. All correlations are significant at the 0.01 level (one tailed).

hour (-0.2, 6.4) when comparing AHI_{np} with AHI_{th} using the AASM alternative hypopnea definition. Despite the small magnitude of some differences, all were significant at the $P < 0.001$ level. As expected, indices derived from the nasal pressure sensor alone were almost always larger than from the combina-

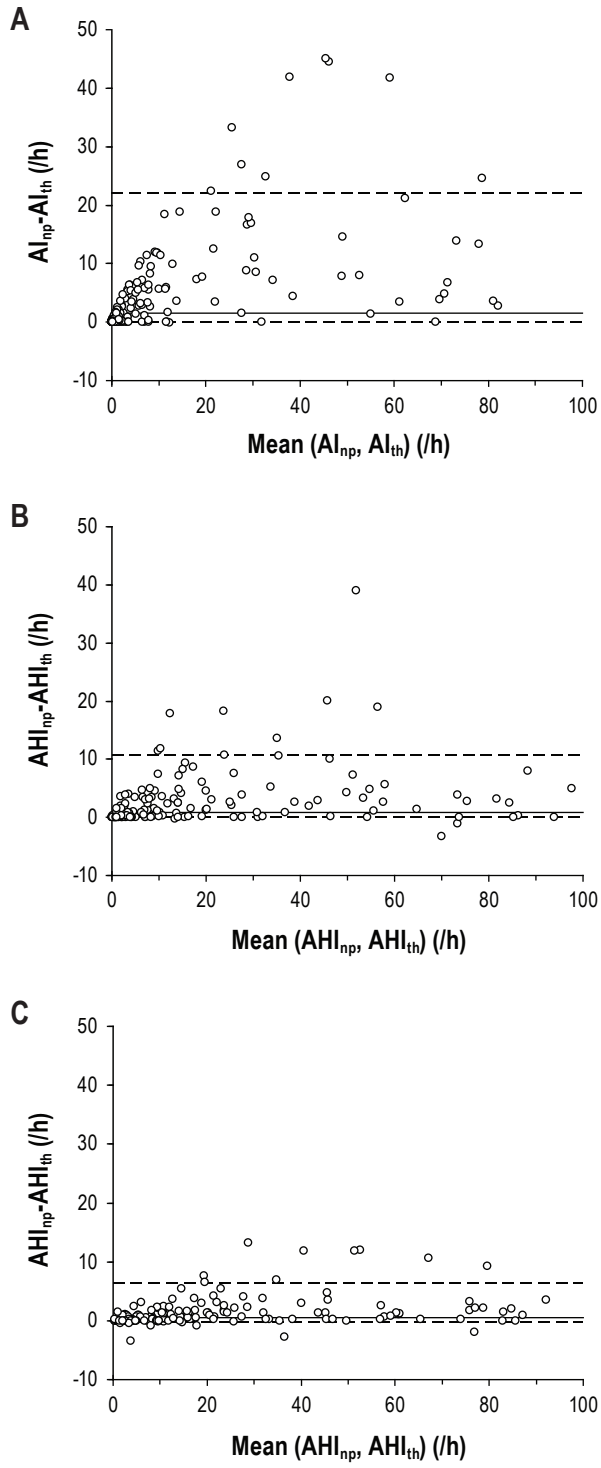

Figure 3—Bland-Altman plots illustrating agreement between measurements: **(A)** AI_{np} and AI_{th}, **(B)** AHI_{np} and AHI_{th} using the AASM recommended hypopnea definition and **(C)** AHI_{np} and AHI_{th} using the AASM alternative hypopnea definition. Solid line represents median difference. Dashed lines represent 5th and 95th percentiles. All differences in median values are significantly different to zero ($P < 0.001$)

tion of thermal sensor and nasal pressure sensor, but there were large individual differences.

OSA Diagnosis

The sensitivity and specificity of AHI_{np} with reference to AHI_{th} as the "gold standard" was calculated at AHI cutpoints between 5 and 60 events per hour. The sensitivity and false negative rate for AHI_{np} is excellent throughout (mean sensitivity 99.9%, mean false negative rate 0.1%), reflecting the observation that AHI_{np} is almost invariably greater than AHI_{th}. Figure 4 shows the false positive rate (1-specificity) of AHI_{np} compared with AHI_{th} for both $AASM_{rec}$ and $AASM_{alt}$ hypopnea definitions. An exponential best-fit line has been added to visualize the trend between discrete data points and to allow estimation of the false positive rate at conventional cutpoints of 5, 10, and 15 events per hour (Table 3). The false positive rates for AHI_{np} were significantly greater than 0 ($P < 0.0001$), and the false positive rate for AHI_{rec} was significantly greater than for AHI_{alt} ($P = 0.0002$). The false negative rates were not significantly different from 0.

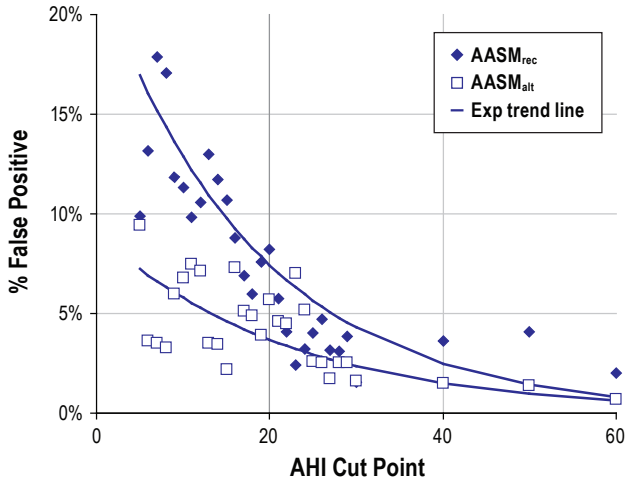

Figure 4—Change in false positive rate using AHI_{np} instead of AHI_{th} for OSA diagnosis at various cut points. Closed symbols are using the $AASM_{rec}$ hypopnea definition and open symbols the $AASM_{alt}$ hypopnea definition. Least squares best fit exponential trend lines asymptotically approaching zero are shown for each definition.

Table 3—Modeled false positive rate, in percentage, for AHI measured with nasal pressure sensor alone against AHI measured with thermal sensor and nasal pressure sensor (AHI_{th}) for various AHI cutpoints and hypopnea definition

	AHI_{th} cutpoint, events/h		
False positive rate (%)	**5**	**15**	**30**
AHI_{np} (Recommended)	16.9	9.8	4.3
AHI_{np} (Alternative)	7.2	4.6	2.4

AHI_{np}, apnea-hypopnea index (AHI) measured with nasal pressure sensor alone; AHI_{th}, AHI measured with thermal sensor and nasal pressure sensor.

DISCUSSION

This study has confirmed that use of the nasal pressure sensor alone rather than the AASM recommended combination of oronasal thermal and nasal pressure sensors results in significant differences in AI and AHI but that the impact on AHI is dependent on the hypopnea definition used.

Oronasal thermal sensors measure temperature from 2 positions around the nares and 1 position in front of the mouth. They produce a composite signal from the 3 inputs. Temperature in the vicinity of the nose and mouth reflects airflow, increasing during expiration and decreasing during inspiration as ambient air is inspired. They have been used for many years in polysomnography, and it has long been recognized that the signal produced is not proportional or even related to airflow.[18-24] As suggested in the evidence review[25] underpinning the AASM manual, the sensitivity of oronasal thermal sensors to small flow makes them appropriate for use in the detection of complete airflow cessation, and, hence, the AASM recommend that they be the sensor used for detecting apnea.

The nasal cannula acts as a Pitot tube[26] producing pressure changes that are variably proportional to flow past the open ends of the cannula. The nasal cannula responds rapidly and produces a close approximation of the flow past the cannula throughout the breath.[27,28] Nasal pressure transducers record only nasal airflow, meaning that they will overestimate the breathing disturbance in the presence of oral breathing.

We expected that the inability of the nasal pressure sensor to detect oral breathing and the reduced sensitivity at low flow rates, relative to the thermal sensor, would result in an increased number of apneic events detected with the nasal pressure transducer. This is confirmed by the data from this study, which show that the median AI in this group of patients presenting for investigation of OSA is 2.1 per hour using a thermal sensor and 6.1 per hour using the nasal pressure transducer. The Bland-Altman plot (Figure 2A) shows that 27 of 164 patients had an AI_{np} that was more than 10 events per hour greater than AI_{th}, whereas only 1 of the 164 patients had an AI_{th} that was greater than AI_{np}. A number of groups have compared the derived AI or AHI from a nasal pressure transducer and thermal sensor.[10,29-33] Consistently, these studies reported the detection of a higher number of apneas when a nasal pressure transducer is used, compared with a thermal sensor, with differences ranging from 30% to 50%.[34,35] This is similar to this study, in which the mean difference between AI_{np} and AI_{th} was 5.3 (4.0, 6.7) events per hour (mean, 95% confidence interval), a difference of 51%.

The AHI rather than AI is, however, the commonly used metric for the clinical diagnosis of OSA. The important difference in this study is that we examined the impact of changing the sensor used to score apnea on AHI in addition to AI. The finding that AI_{np} is different from AI_{th} does not necessarily mean that AHI_{np} will be different from AHI_{th} because events that appear as apneas using a nasal pressure sensor but fail the definition of apnea using the thermal sensor, for example, may still be scored as hypopneas and, hence, be counted in the AHI. However, given that the AASM hypopnea definitions require either a desaturation or, in the case of the $AASM_{alt}$ definition, an arousal, it is likely that some of these events may not meet the definition of hypopnea. It also follows that hypopnea definitions may impact on the number of events subsequently clas-

sified as hypopnea, so it was important to examine the impact of both the recommended and alternative AASM definitions of hypopnea on AHI.

As expected, this study has shown that, when AASM criteria for hypopnea are used, the differences between AHI_{np} and AHI_{th} are less than the differences between AI_{np} and AI_{th}. When the AASM recommended definition is used, the difference between mean AHI_{np} and AHI_{th} was 2.6 (1.9, 3.3) events per hour, a difference of 15%. When the AASM alternative definition is used, the mean difference was 0.7 (0.4, 0.9) events per hour, a difference of only 3%.

The difference in findings with different hypopnea definitions relates to the more rigorous AASM recommended definition requiring a 4% oxygen desaturation criterion to be met in addition to reduced airflow for a hypopnea to be scored.[1] It is apparent that there are a number of events that meet the criteria for apnea if a nasal pressure sensor is used, but fail to meet the criteria for apnea if thermal sensor is used, and that *do not* become a hypopnea under the AASM recommended definition that requires a 4% oxygen desaturation. There are fewer of these events that fail to meet the AASM alternative hypopnea definition that may be scored with a 3% desaturation or an arousal. As a result, when a nasal pressure transducer is used to detect apnea, the difference in AHI using $AASM_{alt}$ is smaller than the difference using $AASM_{rec}$. This study also examined the impact of use of a nasal pressure sensor alone on OSA diagnosis using various cutpoints. We have shown that, when compared with the AASM recommended combination of nasal pressure sensor and thermal sensor, higher cutpoints are associated with greater specificity and fewer false positive diagnoses (Figure 4 and Table 3). This likely reflects the patients in the group that reach higher cutpoints, namely those with severe sleep apnea, who might be expected to have more clear-cut respiratory events and more oxygen desaturation than does the milder group. Furthermore, the use of the AASM alternative hypopnea definition results in better specificity than use of the AASM recommended hypopnea definition. We have also confirmed that at all cutpoints examined the sensitivity of using AHI_{np} was not significantly different from 100%, reflecting that fact that no subject had an AHI_{np} that was markedly less than AHI_{th}.

The data from Ruehland et al.[6] suggest that, to maintain consistency with previous Chicago criteria, the cutpoint for the diagnosis of severe OSA should be reduced from 30 events per hour to approximately 18 per hour using $AASM_{alt}$ or to 11 per hour using $AASM_{rec}$. At the lower cutpoint of 18 events per hour using $AASM_{alt}$, the estimated false positive rates of OSA diagnosis of using nasal pressure sensor alone was 4.0% (Figure 4). At the lower cutpoint of 11 events per hour using $AASM_{rec}$, the corresponding false positive rate was 12.2%. This suggests that, at these diagnostic cutpoints, the use of the $AASM_{alt}$ hypopnea definition and a nasal pressure transducer alone will result in relatively few misclassifications of patients presenting for the diagnosis of OSA, compared with using the $AASM_{rec}$ hypopnea definition.

This study also measured signal loss using either sensor in this unselected group of patients studied under real-life diagnostic laboratory conditions. We found that there was substantial thermal sensor signal loss for 7% of the studies and substantial nasal pressure sensor loss in only 2.5% of studies. These values are similar to those reported by other authors.[20,21]Berg et al.[18] compared nasal pressure and thermal sensors to body plethysmography and suggested that signal loss from displacement of a thermal sensor was more pronounced than from the nasal pressure sensor. When both nasal pressure sensor and thermal sensor were used (as in this study), it is more convenient and comfortable for the patient to place the nasal pressure sensor first and the thermal sensor second, meaning that the thermal sensor is more susceptible to displacement. These findings should not be extrapolated to pediatric studies, in which signal loss of up to 29% has been reported in some studies.[36]

One of the major criticisms of nasal pressure transducers is the absence of an oral breathing sensor. The fact that only 2.5% of the studies had significant portions with inadequate nasal pressure signal quality reflects the proposition that exclusively oral breathing during sleep is uncommon,[19,21,35,37,38] even in patients with OSA.[39]

This study provides limited support for the use of nasal pressure sensors as an adequate substitute for oronasal thermal sensors in situations in which the oronasal thermal sensor fails or in which it is impractical or undesirable to place both nasal pressure and thermal sensors on the patient. Although the AHI is not identical to that obtained using the full AASM recommended montage and scoring criteria, differences are unlikely to be clinically important in routine laboratories that score studies using the AASM alternative hypopnea definitions. In our sample of 164 patients, the estimated false positive rate for the diagnosis of OSA was 4.6% and 2.4% at AHI cutpoints of 15 or 30 events per hour, respectively. If the laboratory uses the AASM recommended definition, specificity is poorer using nasal pressure alone, with false positive rates of 9.8% and 4.3% at cutpoints of 15 and 30 events per hour.

Although we have not directly measured the effect of using nasal pressure to detect apnea during a *temporary* loss of oronasal thermal sensor, as recommended by AASM,[1] the results we have presented suggest that any impact is likely to be small, particularly when the $AASM_{alt}$ hypopnea definition is used.

A potential limitation of the current study is that it is retrospective, using data that were collected under the protocols in place in a routine adult diagnostic sleep laboratory, and, as a result, no special effort was made to correct poor-quality signals in either thermal or nasal pressure sensor. However, this could also be construed as an advantage because the study is more likely to be representative of real-life practice than when special efforts are made to collect high-quality data in a research study. The study was also from a single laboratory with only 3 scorers responsible for the initial scoring and only 1 scorer responsible for rescoring of polysomnograms, although all scorers were trained and enrolled in an external polysomnography-scoring proficiency testing program, which was conducted in conjunction with other Australian and New Zealand laboratories.[14] Because the study was retrospective, it is also possible that the investigator who rescored studies using different sensors and different definitions may have added a bias because she could see the original event scoring; however, she was blinded to the overall AHI of the study. Although the laboratory practices were considered to be standard, it is possible that alternative practices, such as the placement of thermal and nasal pressure sensors and use of an oximeter with an 8-second averaging time might have impacted on the measured AHI. However, we consider that this would have impacted equally on

all scoring montages and, hence, would not have affected the relative AHI values.

The use of data from a single laboratory limits the generalizability of the sensitivity and specificity data for diagnosis of OSA. We attempted to minimize the effect of using arbitrary cutpoints by examining sensitivity and specificity continuously through the range of 5 to 60 events per hour.

CONCLUSION

This study shows that if only a nasal pressure sensor is used to detect apnea and hypopnea, the AI and AHI are greater. Therefore this study confirms that the oronasal thermal sensor is necessary to produce results which conform precisely to AASM guidelines.[1] However, when the AASM alternative definition of hypopnea is used, the average differences are small and likely not clinically important, although there are interindividual differences. If the AASM recommended definition of hypopnea is used, the differences are greater and both sensors should be placed to ensure that appropriate diagnosis, according to AASM guidelines, is reached in all patients.

The modest size of the differences in AHI and the modest impact on OSA diagnosis, particularly with the $AASM_{alt}$ hypopnea definition, supports the view of AASM that the nasal pressure transducer is an adequate alternative to the oronasal thermal sensor when it fails.

This study also provides guidance to clinicians who may be considering the need to place both types of airflow sensors and gives confidence that, for limited-channel devices, such as are commonly used in home-based polysomnography, the impact of not using a thermal sensor may be small relative to other approximations inherent in these devices. If the equipment does not have the capacity to use both flow sensors, the nasal pressure sensor should be used and the AASM alternative definition of hypopnea followed. This will ensure that differences from studies recorded using the full AASM montage are minimized. Caution should be used in applying these results to pediatric studies in which signal quality issues and the nature of respiratory events may be different.

ACKNOWLEDGMENTS

Institutions at which work was performed: Royal Adelaide Hospital, Adelaide, South Australia, Australia, and Institute for Breathing and Sleep, Austin Health, Heidelberg, Victoria, Australia.

DISCLOSURE STATEMENT

This was not an industry supported study. Mr. Rochford has received research support from Compumedics Australia and is a director of Respiratory QA Inc. Mr. Ruehland has received medical equipment support from Resmed Australia, Philips Respironics, and Fisher & Paykel Healthcare and is a director of Respiratory QA Inc. Dr. Thornton has received research support from Actelion Pharmaceuticals and is a director of Respiratory QA Inc. The other author has indicated no financial conflicts of interest.

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