ASTA/ASA Addendum to AASM Guidelines for recording and scoring of paediatric sleep

April 2011

To be used in conjunction with the 2007 AASM Manual for the Scoring of Sleep and Associated Events

Statement of Intent

This document provides additional guidelines and recommendations for the recording and scoring of sleep and associated events for paediatric polysomnography being performed in Australasian sleep laboratories. These guidelines are intended for full channel, attended polysomnography in the clinical setting and should be used in conjunction with the 2007 AASM Manual for the Scoring of Sleep and Associated Events. While they don't specifically cover unattended, community or limited channel studies, they may still prove a useful reference for those types of sleep study.

Next review date: July 2013

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EXECUTIVE SUMMARY

The American Academy of Sleep Medicine (AASM) manual for the scoring of sleep and associated events includes paediatric recommendations. There has been concern that the AASM rules fail to recognise more subtle events that may occur in paediatric sleep. The Australasian Sleep Association/Australasian Sleep Technologists' Association (ASA/ASTA) Paediatric Working Party largely recommend the adoption of the AASM rules for scoring with additional recommendations (as another recommendation category to that used in the AASM manual) to be used at the discretion of the clinician or researcher.

Recording and Technical Specifications

- The use of the recording parameters recommended by the AASM should be adopted in paediatric sleep studies, noting the AASM requirement for continuous pCO_2 measurement, and with the additional ASA/ASTA recommendation for continuous audio-visual recording.
- ASA/ASTA additionally endorse
    - Diaphragm/intercostal EMG as alternative (or adjuvant) measures of respiratory effort.
    - Piezo sensor or decibel meter as alternative measurements of snoring sounds.
    - Pulse Transit Time and Peripheral Arterial Tonometry as optional recording parameters.

Recording and Scoring of Sleep and Arousals

The AASM rules and nomenclature for the scoring of sleep and arousals should be adopted with the following clarification, adaptations and alternatives:

- Minimum age alternative: ASA/ASTA endorses the optional use of the Anders infant sleep criteria (Quiet and Active Sleep) beyond two months of age on a case-by-case basis where this appears more developmentally appropriate to the scorer. The AASM rules should be used for scoring of sleep stages once there is sufficient EEG development (sufficient amounts of slow wave activity, spindles and K complexes) to apply these rules, rather than the use of a mandatory age cut-off as recommended by the AASM.
- N2 arousal optional rule: ASA/ASTA provides an optional alternative / clarification of the AASM rule for scoring the end of N2 sleep in the event of an arousal (N2 sleep only reverts back to N1 sleep after a cortical arousal if the majority of the epoch meets N1 staging criteria).
- Movement epochs alternative rule: An optional alternative rule allowing scoring of movement epochs is provided.
- In infants <6 months, arousals should be scored according to the International Paediatric Working Group on Arousals.
- Sub-classification of arousals as respiratory, limb movement, external/staff or spontaneous types is described.
- The scoring of autonomic/subcortical arousals is described and optional. These arousals may be commented on in the report, but should not be included in the Arousal Index. .

Recording and Scoring of Respiratory Events

- Paediatric respiratory scoring rules are recommended to be used up to the age of 18 years. Adult rules can be applied from age 13 years with the application of the alternative hypopnoea rule.
- The AASM rules for scoring respiratory events should be adopted with the following clarifications, adaptation and alternatives:
  - As per the AASM manual, the use of a thermal sensor for apnoea detection and nasal pressure sensor for hypopnoea detection is recommended. Clarification of which alternative sensors may be used when the primary one fails is provided.
  - As per the AASM manual, respiratory inductance plethysmography is recommended as the primary effort signal. The roles of alternative/adjuvant signals are discussed.
  - In contrast to AASM, the sub-classification of hypopnoea into central or obstructive, without the use of calibrated respiratory inductance plethysmography or invasive pressure manometry is endorsed, although caution is advised, particularly in children with neuromuscular disease and infants. The role of adjuvant signals in making this classification is described.
  - As per AASM, the scoring and reporting of Respiratory Effort Related Arousals (RERAs) is recommended given that the AASM hypopnoea definition may fail to count events of lesser severity. The extension of the RERA rule to include events associated with desaturation (>3%) +/- arousal (RERAD) is endorsed. Neither should be included in the calculation of the AHI to be consistent with AASM AHI. Laboratories may elect to report a separate ORDI including these events for internal reasons.
  - The AASM definition for hypoventilation (>25% of sleep time above 50mmHg) was endorsed with the proviso that sleep hypoventilation only be scored when there is a clear rise from awake to asleep (≥10mm Hg) and REM hypoventilation when there is a clear rise from NREM to REM (≥3 mm Hg).
  - The definition of periodic breathing has been expanded and may be scored when the breathing meets the AASM paediatric rule or the AASM adult rule for Cheyne Stokes respiration.

OVERVIEW OF DIFFERENCES BETWEEN AASM RULES AND ASTA/ASA RECOMMENDATIONS

The following table summaries how the ASTA/ASA guidelines for recording and scoring of sleep and associated events differs from the AASM rules, terminology and technical specifications. Refer to the corresponding numbered section in this document for specific details.

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INTRODUCTION AND DEVELOPMENT PROCESS

The American Academy of Sleep Medicine (AASM) Manual for the Scoring of Sleep and Associated Events (2007), together with associated documentation (1-3), provides guidelines for polysomnography recording and interpretation which have been valuable in standardising practice, particularly in North America. As part of the review process, the 2007 AASM guidelines addressed the issue of recording and scoring paediatric polysomnography. The corresponding background paper in the Journal of Clinical Sleep Medicine (4) provides a comprehensive discussion of the decision making processes which led the committee to recommend the variations to the adult rules which should be applied to paediatric studies.

Subsequent to the publication of the 2007 AASM scoring manual, the Australasian Sleep Association (ASA) and Australasian Sleep Technologists Association (ASTA) undertook to produce two documents which provided recommendations for the application of the AASM rules in Australasian sleep centres. The first document focuses specifically on the recording and scoring of adult sleep (5) while this document sets out recommendations for the recording and scoring of paediatric sleep. The information contained within this document must be read in the conjunction with the AASM scoring guidelines (1), and with the ASA/ASTA commentary on the AASM rules for scoring sleep and associated events in adults (5).

Prior to the publication of the AASM manual, an Australasian paediatric working party (6) had suggested local modifications to the existing paediatric polysomnography scoring rules primarily aimed at addressing areas that were unclear and providing a basis for improved intra- and inter-laboratory scoring concordance. Where these local clarifications or modifications aid in providing guidance to scorers without creating significant inconsistency with the adult rules or the AASM paediatric rules, they should be adopted.

A number of paediatric sleep centres have expressed concern that the AASM rules fail to recognise more subtle events occurring in paediatric sleep. Whilst this review concurs with this view, it does not preclude the measurement of events which may fail to meet AASM criteria but which may be considered important in a holistic clinical examination of paediatric sleep. The importance of these additional findings in terms of clinical outcomes is uncertain and until there is evidence of their significance they should not be included in the standard measures of apnoea-hypopnoea index or arousal index. Further studies are required to link these additional events to clinical outcomes.

This review largely recommends the adoption of the AASM rules for sleep staging, however three AASM changes were contentious - (1) the requirement that sleep staging reverts back to N1 following a cortical arousal in N2, (2) the 2 month post-term age cut-off for staging infant sleep and (3) the discontinuation of scoring movement epochs. Accordingly, the ASTA/ASA paediatric working party agreed to set out alternative sleep scoring rules for these three topics to be used at the discretion of the clinician or investigator. These alternative scoring rules will be reviewed periodically to determine if their use is appropriate, in anticipation that new studies addressing the effects of the new AASM scoring rules and revisions of the AASM rules will be undertaken. The ASA/ASTA working party also have sought to largely adopt the AASM respiratory rules while allowing for the additional identification of more subtle events.

This document makes recommendations only where they differ from the recommendations in the other documents. Where no comment or clarification is made on a particular issue, the AASM rules apply. Of particular note, the adoption of AASM rules are likely to lead to alterations in normal ranges for sleep stages in children, and affect the AHI and thus diagnostic and severity criteria for obstructive sleep apnoea. Further research is needed on the magnitude of this effect and its impact on outcome of various disorders of sleep.

RECOMMENDATION LEVEL FOR RULES

Each rule in the new AASM manual is accompanied by a recommendation level (1). To be consistent with the AASM manual, this document uses the same terminology and definitions:

Recommended	Application of these rules are recommended for the recording and scoring of sleep and associated events.
Alternative	Alternative rules may be used instead of recommended rules at the discretion of the clinician or investigator.
Optional	The use of optional rules may be used at the discretion of the clinician or investigator for events encountered infrequently, events of unknown physiological significance or for events for which a consensus decision on scoring could not be reached.

However, in reviewing the AASM rules ASTA/ASA have also suggested additional sensors that may be used in paediatric sleep studies and have provided additional interpretation rules for the scoring of sleep and associated events. These suggestions are identified as “additional” in this document.

Additional	Additional rules and interpretations proposed by ASTA/ASA which may be used to supplement the AASM recording and scoring rules.

RECORDING SPECIFICATIONS

The AASM manual recommends the same recording parameters for children as for adults with the addition of continuous CO_2 monitoring. Given the complexity of paediatric sleep and breathing problems ASA/ASTA suggest that additional channels of information should be recorded to provide additional confirmatory or diagnostic information. Where additional channels of data are recorded, caution must be exercised in how this data is used if consistency within and between paediatric laboratories is to be achieved.

Recommended Recording Parameters

PSG Recording Parameters for children	Source	Recommended Level
EEG	AASM	Recommended
EOG (note AASM recommends M2 only, some centres use M1)	AASM	Recommended
Chin EMG	AASM	Recommended
ECG	AASM	Recommended
Airflow		
- Nasal Pressure	AASM	Recommended
- Thermocouple / thermostat	AASM	Recommended
Oximetry	AASM	Recommended
Respiratory effort		
- Thoracic and abdominal respiratory inductance plethysmography	AASM	Recommended
- Oesophageal pressure	AASM	Alternative
- Diaphragm / intercostal EMG[a]	ASA/ASTA	Alternative
Body position	AASM	Recommended
Snoring sounds – microphone	AASM	Recommended
Snoring sounds – piezo sensor[b]	ASA/ASTA	Alternative
Snoring sounds – decibel meter[b]	ASA/ASTA	Alternative
Carbon dioxide measurement[c]		Recommended
- Transcutaneous CO_2	AASM	(use at least one of these two)
- End tidal CO_2	AASM	
Audio Video recording[d]	ASA/ASTA	Recommended
Pulse oximeter plethysmographic waveform[e]	ASA/ASTA	Optional
PAP Pressure[f]	ASA/ASTA	Recommended
Pulse transit time[g]	ASA/ASTA	Optional
Peripheral arterial tonometry[g]	ASA/ASTA	Optional

[a] The recording of diaphragmatic EMG (7, 8) or intercostal EMG (9) signals can provide non-invasive estimates of respiratory effort to assist in sub-classification of respiratory event types. However, consistently obtaining adequate signal quality can be challenging.

[b] Refer to the ASTA/ASA commentary on adult scoring rules (5) for a more detailed discussion of using these sensors.

[c] End-tidal carbon dioxide measurement is useful for estimation of hypoventilation, with the AASM guidelines defining hypoventilation as more than 25% of the sleep time spent with a $P_{ET}CO_2$ of more than 50 mmHg (see below)(1, 10, 11). However, the end-tidal pCO_2 cannula may be poorly tolerated and subject to artefact from nasal obstruction or secretions. Transcutaneous carbon dioxide measurement is more reliable in children than adults and may provide better information about hypoventilation.

(d) Audio-video recording is considered a recommended adjunct to the electrophysiological signals in the scoring of sleep in children, especially infants (4).

(e) The recording of the plethysmographic waveform derived from the pulse oximeter provides an independent measure of oximeter signal quality and may be useful in deciding whether falls in oxygen saturation are real or an artefact due to poor signal (12).

(f) Measurement of respiration during PAP studies is essential for assessing treatment efficacy. The discussion in the ASTA/ASA adult guidelines (5) relating to the measurement of PAP is appropriate in the paediatric setting - refer to this document for a more detailed discussion of measuring PAP.

(g) Pulse transit time (13) and peripheral arterial tonometry (14) are techniques which provide evidence of autonomic arousal and may be important and appropriate in the assessment of sleep disruption in paediatric studies.

Recommended Sampling Rates And Filter Settings

AASM Recommended Parameters	**Sampling Rate (Hz)**	**Low Frequency Filter (Hz)**	**High Frequency Filter (Hz)**
EEG	500	0.3	35
EOG	500	0.3	35
EMG	500	10	100
ECG	500	0.3	70
Respiration	100	0.1	15
Oximetry	25	N/A	N/A
Body Position	1	N/A	N/A
Snoring sounds - microphone	500	10	100
ASTA/ASA Alternative Parameters			
Snoring sounds – piezo sensor	100	0.1	15
Snoring sounds – decibel meter	25	DC coupled	DC coupled
ASTA/ASA Additional Parameters			
Pulse oximeter plethysmographic waveform	500	N/A	N/A
Transcutaneous carbon dioxide	64	N/A	N/A
End tidal carbon dioxide	64	N/A	N/A
PAP Pressure	100	0.1	15
Pulse transit time*	N/A	N/A	N/A
Peripheral arterial tonometry	N/A	N/A	N/A

***** If recording pulse transit time the pulse oximeter plethysmographic waveform and ECG will all need to be sampled at 500Hz.

EEG MEASUREMENT

The AASM Manual defines recommended rules for the scoring of sleep in children aged greater than two months post-term. The rules include definitions of paediatric-specific EEG patterns such as the dominant posterior rhythm which requires placement of occipital leads for detection and hence occipital leads should be considered mandatory for paediatric studies. In relation to the use of frontal leads, a small paediatric study (15) looking at the use of frontal leads to improve detection of arousals failed to find a difference, however they may improve detection of K complexes and slow-wave activity which have increased importance in paediatric studies. Anecdotal evidence suggests that the effects of incorporating the additional EEG derivations recommended by the AASM may be more pronounced in infants and young children, who show marked topographical differences in EEG dynamics during development. As a result, frontal leads are recommended for use in paediatric studies as per the AASM Manual.

Recommended EEG derivations are:

- C_4-M_1 with C_3-M_2 as a backup
- O_2-M_1 with O_1-M_2 as a backup
- F_4-M_1 with F_3-M_2 as a backup

The placement of chin EMG leads in paediatric studies may be more problematic than it is for adult studies and some latitude in the placement is acceptable.

VISUAL SCORING OF SLEEP

AASM rules for scoring sleep in infants aged less than 2 months post term

For infants aged less than two months post-term the AASM scoring manual refers to the paediatric discussion paper (4) which provides a detailed description of changes in sleep physiology with maturation and discusses the importance of EEG rhythms not present in children or adults. The AASM paediatric taskforce suggested that the Anders infant sleep criteria (16) were suitable for scoring sleep and wake states in infants 46 to 48 weeks post-conceptional age until sleep spindles are observed. The discussion paper is equivocal in its terminology but continues to use the terms Quiet and Active sleep noting that they are likely precursors of NREM and REM sleep. For simplicity, consideration should be given to the use of the terms NREM and REM sleep instead of the historical quiet and active sleep.

AASM rules for scoring sleep in children and infants aged 2 months post-term or older

In infants older than 2 months post-term the AASM scoring manual recommends that the nomenclature of NREM and REM sleep should be used rather than the traditional quiet and active sleep because: "*1) all the EEG and polysomnographic features of REM sleep are present by this age; 2) for convenience and simplicity; and, 3) quiet sleep, if not NREM sleep by this age, is at least 'not REM sleep'." (4)*

To accommodate the variability in maturation of infant sleep, an additional sleep stage, N, has been proposed which represents epochs of sleep lacking 0.5 – 2 Hz slow wave activity or recognisable stage 2 landmarks (spindles or K complexes). As a result, four possible scoring scenarios for infants are presented in the AASM

scoring manual to account for variation in sleep EEG development (particularly with respect to appearance of stage 2 sleep landmarks and delta activity). Once the sleep EEG shows sufficient amounts of slow wave activity, spindles and K complexes, the same sleep scoring terminology as used for adults is to be used for children (W, N1, N2, N3, R).

Implications

Some members of the ASTA/ASA paediatric working party were concerned that the two month post-term age demarcation for sleep staging in infants may be too early. There is significant individual variation in the development of the central nervous system in normal infants, which is reflected in the sleep EEG. The two month post-term age limit was chosen by the paediatric taskforce because it is when spindles can first be seen in some infants. However emergence of sleep spindles is developmentally variable occurring between 2-4 months of age and before this time spindles are often fragmentary and difficult to clearly distinguish (17). Furthermore, infants with neurodevelopmental disorders may show delayed sleep EEG development.

Recommendation

Accordingly, as an alternative to the AASM recommendations, the ASTA/ASA paediatric working party proposes that there is no upper age limit for the application of the Anders infant sleep criteria and that the visual scoring of infant sleep be based on an individual infant's specific EEG characteristics. Thus sleep is scored on the basis of an individual's developmental trajectory irrespective of their chronological or corrected age. Once the sleep EEG meets the criteria for AASM scoring (utilising the four possible scoring scenarios) this system of scoring should be used.

Staging of Sleep (once EEG development meets criteria for AASM scoring)

The AASM rules for sleep staging in children more than 2 months post term are described in detail in the AASM manual. A review of these rules and their impact in a group of 45 normal healthy children has been published by Novelli *et al*. (18) Their findings were consistent with two studies in adults (19, 20) and showed a large increase in N1, a small increase in R and a concomitant decrease in N2. Unlike the adult studies, there was no change in N3 (previously slow wave sleep). The increase in N1 sleep may be more pronounced in infants and young children where there is an increased number of spontaneous arousals and a variable time course in the development of stage 2 sleep landmarks. The Novelli study also found a small reduction in sleep latency and an increase in the number of stage changes (18). These changes were not likely to be clinically important. At this time, there is insufficient evidence to determine the net effect of the AASM rules on the total amount of sleep or wake, but for consistency it would be preferable if the AASM rules were adopted. More studies addressing the effects of the change in scoring associated with adoption of the AASM rules are needed, with a view to also deriving new normative values.

While recognising the importance of consistency in scoring, some Australasian sleep laboratories have reservations about some of the changes in the AASM sleep scoring rules. Two areas are of particular concern: (1) the requirement that sleep staging reverts back to N1 following a cortical arousal in N2 and (2) the

discontinuation of scoring of movement epochs. Alternative/Optional scoring rules for these two areas are outlined below in the relevant sections.

Stage W (Wakefulness)

- It is recommended that the AASM definition and scoring rules for Stage W be adopted.

Stage N1

- It is recommended that the AASM definition and scoring rules for Stage N1 be adopted.

Stage N2

- It is recommended that the AASM rules for the start of Stage N2 be adopted.
- It is recommended that the AASM rules for the continuation of Stage N2 be adopted.
- It is recommended that the AASM rules for the termination of Stage N2 be adopted **or** that the ASTA/ASA optional rule for the termination of Stage N2 be adopted.

Optional ASTA/ASA rule for scoring the end of stage N2:

End stage N2 sleep when one of the following events occurs:

A. Transition to stage W, N1, N3 or R.

B. A cortical arousal and/or major body movement and the majority of the epoch meets N1 staging criteria (change to N1 until a sleep spindle or a K complex unassociated with arousal occurs).

Stage N3

- It is recommended that the AASM definition and scoring rules for Stage N3 be adopted.

Stage R

- It is recommended that the AASM definition and scoring rules for Stage R be adopted.

Major Body Movements

- It is recommended that the AASM definition and scoring rules for epochs containing major body movements be adopted **or** that the ASTA/ASA alternative scoring rule for epochs containing major body movements be adopted.

Alternative ASTA/ASA rule for scoring epochs with major body movements:

A. The AASM definition for major body movement should be adopted.

B. If alpha rhythm and/or eye opening is observed for any part of the epoch, score as wake.

C. Stage as wake if the preceding or following epoch is scored as wake.

D. Score as wake if there are more than 2 consecutive epochs of major body movements.

E. Otherwise score the epoch as movement.

Explanation:
Movement epochs are no longer scored using the AASM rules. Instead, epochs obscured by movement are staged as wake if there is any evidence of alpha rhythm or if the preceding or following epoch is scored as wake. Otherwise, the epoch is to be assigned the same sleep stage as the epoch following the movement.

The percentage of movement epochs scored during a sleep study can on occasion provide clinically useful information, as movement is an important part of the arousal pathway in children. Movement may represent a significant disruption to sleep continuity. Although there are no normative data or standardised criteria for evaluating the amount of movement time during sleep, the scoring of movement epochs does provide a clinical impression of sleep quality and fragmentation when viewing the hypnogram which is not necessarily reflected in position changes or arousal indices. The ASTA/ASA alternative rule for scoring epochs containing major body movements therefore retains the classification of movement epochs.

AROUSAL SCORING

Arousals can be scored from occipital, central or frontal EEG derivations.

Scoring Arousals In Children

The AASM rules for arousal scoring in children are not different to those in adults. However the Australasian paediatric working party (6) has previously suggested some additional criteria to the AASM rules to classify arousal types and to define the temporal association between events:

ASTA/ASA additional criteria for classifying cortical arousals

The following arousal types have been defined:

- **Respiratory arousal**: Meets AASM arousal scoring criteria and occurring less than 2 respiratory cycles after the termination of a respiratory event.
- **Limb movement arousal**: Meets AASM arousal scoring criteria and occurring when there is overlap between a limb movement and arousal or when there is < 0.5s between the end of one event and the onset of the other, irrespective of which event (arousal or limb movement) occurs first.
- **External/Staff arousal**: Meets AASM arousal scoring criteria when there is an identified reason for the arousal external to the patient, such as staff entering the room, a parent moving, a loud noise from an adjoining room etc.
- **Spontaneous arousal**: Meets AASM arousal scoring criteria and not meeting one of the above definitions.

If an arousal meets both respiratory and limb movement association rules, a respiratory arousal should be scored.

Scoring autonomic / sub-cortical arousals in children

It should be noted that the use of the AASM rules for scoring arousals in children may fail to recognise a number of EEG or autonomic changes that may be more sensitive markers of sleep disruption. Autonomic changes manifested, for example, by heart rate changes, pulse transit time or peripheral arterial tonometry, may be more sensitive measures of obstructive events than AASM-defined EEG arousals. Australasian sleep laboratories may therefore elect to score subcortical arousals (optional). Sub-cortical arousals may be defined as the simultaneous occurrence of ≥ 2 of the following events for a minimum of 3 seconds duration: an increase in EMG, an increase in HR (>10% from baseline) and/or a body movement. Further clinical outcome studies are required to confirm the importance of these events. Sub-cortical arousals cannot be used towards scoring an event or sleep state change. At this stage it cannot be recommended that non-EEG arousals be counted in the overall arousal index but comment should be made if these events are prevalent in a study.

Scoring Arousals In Infants

The scoring of arousals in infants is unclear in the AASM manual, particularly as the "N" sleep stage is omitted from the arousal scoring rules.

Previously, an international working party (21) has suggested that the use of adult rules in infants fails to adequately recognise arousals, but in the absence of agreement it is recommended that the rules of the AASM be adopted. The paediatric evidence paper (4) stated that arousal scoring in infants (1-6 months of age) requires different criteria (in particular decremental EEG responses) as published by the International Paediatric Working Group on Arousals (21). The use of the latter paper is suggested for studies of infants less than 6 months.

CARDIAC RULES

The AASM cardiac rules note that heart rate in children is higher than in adults but make no additional recommendations. The AASM rules should be adopted.

PERIODIC LIMB AND OTHER MOVEMENTS

The AASM rules for scoring periodic limb movements in sleep and other movements in children are not different to those in adults and should be adopted.

RESPIRATORY EVENT SCORING

Technical Considerations

Airflow Sensors for Respiratory Scoring

Practical considerations may make the placement of both a nasal pressure transducer and thermal sensor difficult in small children. Nevertheless it is the view of the Australasian paediatric working party that every attempt should be made to apply both sensors and that the AASM rules in terms of the use of the sensors to detect apnoea and hypopnoea should be followed. If both sensors cannot be placed, it is preferable to use the nasal pressure sensor rather than a thermal sensor. While the number of apnoeas measured using a thermal sensor may be different to the number measured using nasal pressure, adult data has shown that differences in the sum of apnoea and hypopnoea (AHI) were minimised when the AASM alternative hypopnoea definition was employed (24). This suggests that in paediatric scoring, where only the alternative hypopnoea definition is employed, differences between the two sensors in AHI may be small.

Recommendations

- Both a nasal pressure sensor and an oronasal thermal sensor should be used wherever possible.
- If it is possible to place only one airflow sensor, a nasal pressure sensor should be used.

Respiratory Effort

Oesophageal manometry or calibrated respiratory inductance plethysmography (RIP) measurement is recommended by AASM for the sub-classification of types of respiratory events as obstructive or central. Oesophageal manometry requires the insertion through the nose of a cannula into the lower oesophagus. Oesophageal manometry is difficult in clinical practice and is not widely used because of patient discomfort and awakenings leading to alteration in sleep architecture. Oesophageal manometry however remains the gold standard for evaluation of respiratory effort in the differentiation of central and obstructive apnoea or hypopnoea with abnormal inspiratory pressures below –10 cmH_2O. Calibrated RIP is not widely available. Use of diaphragmatic or intercostal EMG may provide an estimate of respiratory effort, and has technical advantages in children compared to adults. Use of uncalibrated respiratory inductance plethysmography is less satisfactory but more practical for clinical use. In some clinical situations (such as neuromuscular disease), sub-classification is important in determining the underlying cause of the respiratory disturbance and thus guiding treatment. However, caution should be applied in the use of non-quantitative measurements.

Recommendation

- Recommended sensors for detection of respiratory effort are oesophageal manometry, calibrated respiratory inductance plethysmography and uncalibrated respiratory inductance plethysmography.
- Diaphragmatic and intercostal EMG measurement may be used as an alternative measure of respiratory effort during NREM sleep however, during REM sleep only diaphragmatic EMG can be used for the same purpose.

- Video evidence of airway obstruction may also provide confirmatory support for sub-classification of an event as obstructive.

Scoring Respiratory Events

Adult versus Paediatric Respiratory Scoring Rules

The major differences between AASM adult rules and AASM paediatric rules relate to event duration - which may be two missed breaths for paediatric scoring – and the acceptance that only the adult "alternative" hypopnoea rule should be applied in children. The AASM defines rules for scoring respiratory events in children but is equivocal about whether these rules should be used up to the age of 13 years or up to the age of 18 years. Marcus and co-workers (22) examined the effect of using paediatric rules or adult rules in normal healthy children in the age range of 13 to 18 years. They found statistically significant but clinically unimportant differences in AHI between the use of the rule sets and concluded that either could be used. However, a subsequent study in adolescents with OSA (23) found significant differences in diagnostic outcomes when adult rules were used if the hypopnoea rule A was used. No difference was found when hypopnoea rule B (alternative) was applied.

Recommendation

There it is recommended that paediatric rules should be applied to children under 18 years of age (most preferable option), or where adult rules are used for those aged over 13 years, the hypopnoea rule B should be applied.

The scoring of respiratory events is largely based on current AASM recommendations. For details of the scoring recommendations, refer to the AASM guidelines. (1)

Apnoea scoring

- When the signal from the oronasal thermal sensor is adequate, apnoea should be measured from that signal.
- When the signal from the oronasal thermal sensor is not adequate, apnoea may be measured from nasal pressure sensor.
- When the signals from both airflow sensors are inadequate, apnoeas may be measured from calibrated respiratory inductance plethysmography.
- When the signals from both airflow sensors are inadequate, central apnoea but not obstructive apnoea may be measured from uncalibrated inductance plethysmography.
- When the signals from both airflow sensors are inadequate, breath by breath measurement of end tidal carbon dioxide may be used for the detection of apnoea but not hypopnoea.

Hypopnoea scoring

- When the signal from the nasal pressure sensor is adequate, hypopnoea should be measured from that signal.
- When the signal from the nasal pressure sensor is inadequate, hypopnoea may be measured from the oronasal thermal sensor.

- When the signals from both airflow sensors are inadequate, hypopnoeas may be measured from calibrated respiratory inductance plethysmography.
- The AASM recommends sub-classification of hypopnoeas into obstructive or central events only when manometry or calibrated inductance plethysmography is available. The ASA/ASTA acknowledges that Australasian Paediatric Laboratories may elect to make this sub-classification based on alternative or adjuvant channels such as audio-video evidence of airway obstruction, airflow signal characteristics (flattening, notching), uncalibrated inductance plethysmography or diaphragmatic EMG. However, caution should be applied in the use of these measurements and a descriptive comment should be made in the report detailing the nature of events and their classification.

Respiratory event related arousals (RERA)

- The event must be terminated by a cortical arousal (inadvertently omitted from the AASM manual) and normalisation of respiratory signals to pre-event levels.
- In paediatric studies it is recognised that events which fail to meet the definition of apnoea or hypopnoea may be important in the diagnosis of sleep-related breathing disorders and therefore the separate reporting of RERAs is recommended (in contrast to the adult rules where reporting of RERAs is optional).
- The ASTA/ASA paediatric working party suggests counting similar events which fail to meet the definition of apnoea or hypopnoea and are not associated with arousal but are associated with desaturation $\geq$3%. Individual laboratories may consider reporting a RERAD (respiratory event related arousal or desaturation $\geq$3%) index for clinical purposes. Alternatively reporting an oxygen desaturation index which captures these events may be considered desirable.
- RERAs and/or RERADs should not be summed with apnoea and hypopnoea to generate an AHI but may be included in a respiratory disturbance index (RDI). Individual laboratories may choose to report a separate RDI (including central and obstructive events) and/or an obstructive respiratory disturbance index (ORDI) including RERADs (noting that this is not equivalent to the AASM AHI or AASM OAHI).

Scoring Sleep Hypoventilation

The AASM allows hypoventilation to be scored when either good quality end tidal or transcutaneous carbon dioxide levels are increased above 50mmHg for more than 25% of total sleep time. Adjustments to this criterion will however need to be made when good quality data is not available for the whole of sleep time. However, both measurements have technical difficulties and it is recommended that hypoventilation should only be scored when there is a clear difference between values recorded during wake and sleep *and* where the sleep values are above 50mmHg. The use of transcutaneous carbon dioxide measurement is preferred when hypoventilation is suspected as it is less susceptible to artefact such as nasal obstruction or secretions which are common in paediatric populations.

The ASA/ASTA working party also discussed that an increase in transcutaneous CO_2 of ≥10mmHg from wake to sleep, or an average increase of ≥ 3 mmHg from NREM to REM sleep is indicative of significant CO_2 retention.

Periodic Breathing

The AASM rules require a sequence of >3 central apnoeas > 3 seconds (or two missed breaths) in duration each occurring within 20 seconds of the previous event to classify periodic breathing. As a result a series of central hypopnoeas will fail to meet this definition. In contrast, the AASM adult rules (for Cheyne Stokes respiration) allow for central apnoeas or hypopnoeas. If this pattern is observed in a paediatric study it seems appropriate to label this as periodic breathing.

Recording and Scoring Of Respiratory Events - Overview

- Paediatric respiratory scoring rules are recommended be used up to the age of 18 years. Adult rules can be applied from age 13 years as long as the hypopnoea rule B is applied.
- As per the AASM manual, the use of a thermal sensor for apnoea detection and nasal pressure sensor for hypopnoea detection is recommended, but in the absence of an acceptable signal the alternate sensor may be used.
- Australasian laboratories may elect to sub-classify hypopnoeas as obstructive, mixed and central events with the use of video evidence of airway obstruction, uncalibrated inductance plethysmography or diaphragmatic EMG. However, caution should be applied in the use of these measurements, particularly in children with neuromuscular disease and in infants.
- The scoring and reporting of Respiratory Effort Related Arousals (RERAs) is recommended given that the AASM hypopnoea definition may fail to count events of lesser severity. Inclusion of RERAs with desaturation (≥3%) +/- arousal is also recommended. RERAs should not be included in the calculation of the AHI to be consistent with AASM recommendations. Laboratories may elect to report a separate ORDI including these events for internal reasons.
- Sleep hypoventilation should only be scored when there are clear differences between awake and asleep or NREM and REM carbon dioxide levels (≥10mm Hg increase from awake to asleep and/or ≥3 mm Hg increase from NREM to REM sleep).
- Periodic breathing may be scored when the breathing meets the AASM paediatric rule or the AASM adult rule for Cheyne Stokes respiration.

CONCLUDING STATEMENT

The AASM manual is substantially relevant for the scoring of sleep and associated events in paediatrics in Australia and New Zealand. However, the ASA/ASTA Paediatric Working Group have recommended additional criteria that would clarify and enhance the application of the current AASM manual. These are reflected in the recommendations within this document. Formal feedback and review of new literature will be made and these guidelines updated every three years.

SUMMARY OF INDICES – see AASM recommendations in addition.

Index		Definition	Source
AHI	Apnoea Hypopnea Index	Number of apnoeas and hypopnoeas divided by total sleep time	AASM recommended
OAHI	Obstructive apnoea/hypopnoea index	Number of obstructive apnoeas and obstructive hypopnoeas divided by total sleep time	ASTA/ASA recommended
CAHI	Central apnoea/hypopnoea index	Number of central apnoeas and central hypopnoeas divided by total sleep time	ASTA/ASA recommended
ODI	Oxygen desaturation index	Oxygen desaturations ≥3% divided by total sleep time Oxygen desaturations ≥4% divided by total sleep time	AASM optional AASM optional
RERAI	Respiratory effort related arousal index	Number of RERA divided by total sleep time	AASM optional, ASA/STA optional
RERADI	Respiratory effort related arousal and/or desaturation index	Number of RERA and RERAD divided by total sleep time	ASA/ASTA optional
RDI	Respiratory disturbance index	All respiratory events including apnoea, hypopnoea, RERA and RERAD divided by the total sleep time. Each lab should define what events are included.	ASA/ASTA recommended
ORDI	Obstructive respiratory disturbance index	Number of obstructive events including apnoea, hypopnoea, RERA and RERAD divided by the total sleep time. Each lab should define what events are included.	ASA/ASTA optional
CRDI	Central respiratory disturbance index	Number of central events including apnoea, hypopnoea, 'pauses' or other subthreshold central events divided by the total sleep time. Each lab should define what events are included.	ASA/ASTA optional

REVISION HISTORY

Version	**Date**	**Authors**
Version 1.0	12 August, 2010	A Thornton
Version 1.2	25 August, 2010	A Thornton
Version 1.3	26 September, 2010	A Thornton, N Verginis, G Nixon, Y Pamula
Version 2.0	16 December, 2010	G Nixon, N Verginis, M Davey
Version 3.0	16 February, 2011	Y Pamula, S Coussens
Version 3.1	18 February, 2011	Y Pamula
Version 3.2	17 March, 2011	G Nixon
Version 3.3	21 March, 2011	Y Pamula, G Nixon
Version 4.0	10 April 2011	S Suresh
Version 5.0	21 April 2011	ASA/ASTA Paediatric Working Group

All revisions were carried out with input from members of the working group. Of particular mention for their detailed contributions are : Jacob Twiss (Auckland), Jennifer Maul (Perth), Karen Waters (Sydney), Bruce Whitehead (Newcastle), Mandie Griffiths (Melbourne), Bruce Williamson (Sydney).

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