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BRITISH THORACIC SOCIETY GUIDELINE FOR DIAGNOSING AND MONITORING PAEDIATRIC SLEEP-DISORDERED BREATHING

British Thoracic Society
Diagnosing and monitoring paediatric sleep-disordered breathing Guideline Development Group

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Healthcare providers need to use clinical judgement, knowledge and expertise when deciding whether it is appropriate to apply recommendations for the management of patients. The recommendations cited here are a guide and may not be appropriate for use in all situations. The guidance provided does not override the responsibility of healthcare professionals to make decisions appropriate to the circumstances of each patient, in consultation with the patient and/or their guardian or carer.

BTS Guideline for diagnosing and monitoring paediatric sleep-disordered breathing Guideline Development Group

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On behalf of the British Thoracic Society

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British Association of Paediatric Otolaryngology
British Paediatric Neurology Association
British Paediatric Respiratory Society
British Paediatric Sleep Association
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Boxes

Tables

MORE CONTENTS ►

Appendices

Supplemental online appendices

Glossary and Abbreviations

AASM	American Academy of Sleep Medicine
AHI	Apnoea-hypopnoea index
AI	Apnoea indices
BiPAP	Bi-level positive airway pressure
BPD	Bronchopulmonary dysplasia
BTS SOCC	British Thoracic Society Standards of Care Committee
CAHI	Central apnoea-hypopnoea index
CAS	Cleveland adolescent sleepiness
CAS-15	Clinical assessment score-15
CDSR	Cochrane Database of Systematic Reviews
CENTRAL	Cochrane Central Register of Controlled Trials
CI	Confidence interval
CO_2	Carbon dioxide
CPAP	Continuous positive airway pressure therapy
CRSS	Cardiorespiratory sleep study/studies
CSA	Central (or non-obstructive) sleep apnoea
D+	Number of subjects with disease
D-	Number of subjects without disease
ECG	Electrocardiogram
EDS	Excessive daytime sleepiness
EEG	Electroencephalogram
EMG	Electromyogram
ENT	Ear, nose and throat
EOG	Electrooculogram
ERS	European Respiratory Society
ESRS	European Sleep Research Society
GDG	Guideline development group
GPP	Good practice point
GRADE	Grading of recommendations, assessment, development and evaluations
HDU	High dependency units
MSLT	Multiple sleep latency test
Nadir	Lowest oxygen saturation
NHS	National Health Service
OAHI	Obstructive apnoea-hypopnoea index
ODI3	3% oxygen desaturation index
ODI4	4% oxygen desaturation index
OSA	Obstructive sleep apnoea

OSA-18	Obstructive sleep apnoea-18 item questionnaire
PCO_2	Partial pressure of carbon dioxide
PICO	Population, intervention, comparator and outcome
PICU	Paediatric intensive care unit
PSG	PolysomnographyREM Rapid eye movement
SCR	Sleep clinical record
SDB	Sleep-disordered breathing
SPO_2	Oxygen saturation
SRBD-PSQ	Sleep-related breathing disorder scale of the paediatric sleep questionnaire
TN	True negative
TP	True positive

British Thoracic Society guideline for diagnosing and monitoring paediatric sleep-disordered breathing

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SUMMARY OF RECOMMENDATIONS AND GOOD PRACTICE POINTS

Please note that sleep-disordered breathing (SDB) in children without comorbidities is related to snoring and upper airway obstruction and commonly referred to as obstructive sleep apnoea (OSA).

Diagnosing sleep-disordered breathing in children with suspected sleep-disordered breathing

Sleep questionnaires, combined sleep questionnaires and 'protocol-driven' clinical assessments, sleep video recordings and sleep audio recordings

Children without comorbidities

Recommendations

► The Sleep-Related Breathing Disorder scale of the Paediatric Sleep Questionnaire (SRBD-PSQ), with a cut-off of ≥0.33, or Obstructive Sleep Apnoea-18 item questionnaire (OSA-18), with a cut-off of ≥0.60, can be considered for diagnosing moderate-to-severe SDB in children of at least 2 years of age with no comorbidities. If a test questionnaire is inconsistent with clinical features or if a higher degree of diagnostic certainty is required, further tests, such as pulse oximetry, cardiorespiratory sleep studies (CRSS) or polysomnography (PSG), are recommended. (Conditional)

► Sleep questionnaires combined with a 'protocol-driven' clinical assessment can be considered for diagnosing SDB in children, but it should be noted that the sleep clinical record (SCR) is labour-intensive, taking approximately 30 min to complete. If a test questionnaire is inconsistent with clinical features, or if a higher degree of diagnostic certainty is required, further tests, such as pulse oximetry, CRSS or PSG, are recommended. (Conditional)

Good practice points

✓ Clinical questionnaires, combined with clinical examination, can identify moderate or severe SDB with a moderate-to-high sensitivity and low-to-moderate specificity. This may be considered adequate, for example, in relation to deciding whether, or not to pursue surgery to improve the airway (eg, tonsillectomy).

✓ The Clinical Assessment Score-15 (CAS-15) combined sleep questionnaire and 'protocol-driven' clinical assessment can be considered for diagnosing SDB in children. In contrast to the SCR, the CAS-15 takes 10 min to complete but has a reduced sensitivity of moderate.

✓ Sleep questionnaires should not be considered for diagnosing SDB in children under 2 years of age, or if mild SDB is suspected.

Children with comorbidities

Good practice point

✓ Sleep questionnaires should not be considered for diagnosing SDB in children with comorbidities.

Pulse oximetry and CRSS

Children without comorbidities

Recommendation

► For children with suspected SDB, pulse oximetry can be considered as a first-line diagnostic test for SDB. If a test result does not fit the clinical picture, a higher level of investigation, such as a CRSS, may be required (see also Good practice points (GPPs) below). (Conditional)

Good practice points

✓ If pulse oximetry is normal, but there is suspicion of SDB, a CRSS may be useful to identify mild OSA. Sleep video recording may also be considered to give a clearer picture.

✓ If pulse oximetry is abnormal, CRSS are more specific and can discriminate between central and obstructive events.

✓ When analysing and interpreting paediatric pulse oximetry traces, a 4% Oxygen Desaturation Index (ODI4) cut-off of >4/hour and/or a 3% Oxygen Desaturation Index (ODI3) cut-off of >7/hour are suggestive of an abnormality in children over 2 years of age. Baseline mean oxygen saturations (SpO_2) of <95%, desaturations to <90% and clustering and depth of desaturation events should also be considered in pulse oximetry interpretation.[1 2] If one pulse oximetry parameter is considered abnormal when the other parameters are considered normal, a CRSS should be considered.

- ✓ While pulse oximetry is non-discriminatory at all ages, particular caution is required in using oximetry to diagnose OSA in children under 2 years of age as children in this age group are predisposed to central sleep apnoea (CSA) (as a result of developmental immaturity) and oxygen desaturations cannot discriminate between obstructive and central events.
- ✓ If a child is unable to tolerate CRSS equipment, for example children with autistic spectrum disorder, consideration should be given to utilising play therapy techniques to facilitate data acquisition. Consideration should also be given to undertaking CRSS in the home (see 'Home monitoring (pulse oximetry or CRSS)' recommendations and GPPs).
- ✓ If a CRSS test result does not fit the clinical picture, PSG should be considered. An exception to this is when CRSS rules out a diagnosis of SDB and a diagnostic pathway for narcolepsy should be considered.
- ✓ Clinicians are cautioned from using Apnoea Hypopnoea Index (AHI) alone to guide decision-making.
- ✓ If hypoventilation is suspected, please refer to the 'Pulse oximetry and carbon dioxide (CO_2) monitoring' recommendations and GPPs below.

Children with comorbidities

Recommendation

- ► For children with neuromuscular disorders or Down Syndrome predisposing to SDB, CRSS can be considered for diagnosing SDB. (Conditional)

Good practice points

- ✓ Although CRSS can only be recommended as a diagnostic tool for SDB in children with neuromuscular disorders or Down Syndrome, CRSS can be considered as a first line diagnostic tool for children with other comorbidities.
- ✓ If a CRSS is abnormal, the significance of the findings should be carefully considered and the range of potential management options discussed with the child and their family/carer.
- ✓ If CRSS findings are inconsistent with the clinical picture the clinical history should be reviewed giving specific consideration to non-respiratory causes of sleep disorders. Referral to a neurology sleep service for assessment should also be considered.
- ✓ If a CRSS is not available, pulse oximetry can be considered as an initial diagnostic test for SDB in children with comorbid disorders, but if a test result is abnormal caution must be taken in interpreting the results as desaturations may have varying causes. Referral for more complex studies may be required to assess for hypoventilation and determine the cause and mechanisms of desaturation.
- ✓ If a pulse oximetry test is normal, this does not exclude SDB and clinical review should consider repeat/additional testing.
- ✓ Clinicians are cautioned from using AHI alone to guide decision-making.
- ✓ If hypoventilation is suspected, please refer to the 'Pulse oximetry and CO_2 monitoring' recommendations and GPPs below.

Pulse oximetry and CO_2 monitoring

Children without comorbidities

Recommendation

- ► The addition of CO_2 monitoring to pulse oximetry is not recommended for diagnosing SDB in children without comorbidities. (Conditional—by consensus)

Children with comorbidities

Recommendation

- ► The addition of CO_2 monitoring to pulse oximetry should be considered for children with comorbidities and suspected SDB where hypoventilation is suspected, such as patients with neuromuscular disease or patients suspected of central hypoventilation (eg, congenital central hypoventilation syndrome). (Conditional—by consensus)

Good practice points

- ✓ If CO_2 measurements are not consistent with the clinical picture, this should be confirmed using a blood gas measurement. If using a transcutaneous CO_2 monitor, this should be recalibrated first. If the problem is not resolved, consideration should be given to checking and changing the sensor head membrane.
- ✓ Pulse oximetry with CO_2 monitoring can be considered as a screening tool to identify hypoventilation in children with comorbidities, or to assess response to adjustments to ventilatory settings in the home setting.
- ✓ The American Academy of Sleep Medicine (AASM) recommends scoring hypoventilation during sleep when >25% of the total sleep time, as measured by either the arterial PCO_2 or surrogate (transcutaneous or end tidal which is more relevant in paediatrics), is spent with a PCO_2 >50 mm Hg/6.7 kPa.[3]

Home monitoring (pulse oximetry or CRSS)

Recommendation

- ► Home CRSS can be considered for diagnosing SDB in children without comorbidities where the patients and/or carers are deemed appropriate for implementing a home sleep study. If a test result is inconsistent with the clinical picture, or data are incomplete, a repeat study should be offered and consideration should be given as to whether this should be undertaken as an inpatient. (Conditional—by consensus)

Good practice points

- ✓ Home CRSS can be considered for children with comorbidities and pulse oximetry can be considered for children with, or without comorbidities if the patient and carer are deemed appropriate for home sleep studies.
- ✓ Care should be taken in defining 'total sleep time' during home sleep studies as it may differ between centres, for example, some may use total recording time, while some may base it on sleep time documented in the overnight sleep diary.
- ✓ If the data acquired during a home study is fragmented with frequent interruptions due to poor signal quality, consideration should be given to repeating the study as an inpatient.
- ✓ Parents who choose home monitoring should be supported with training in order to optimise data acquisition of sleep studies in the home environment. This training might involve patient leaflets, patient videos or videoconferencing calls with health professionals skilled in setting up sleep studies.

Pulse oximetry/CRSS optimal monitoring time and process

Pulse oximetry motion artefact removal and averaging time

Recommendation

- ► Pulse oximetry should be undertaken using an oximeter with a software algorithm to minimise the influence of motion artefact. (Conditional—by consensus)

Good practice point

✓ Based on the Australasian Sleep Association's 'Overnight oximetry for evaluating paediatric obstructive sleep apnoea: Technical specifications and interpretation guidelines',[4] a short pulse oximetry averaging time of 2–3 s should be used when diagnosing SDB in children.

Pulse oximetry/CRSS optimal monitoring time

Good practice point

✓ Sleep studies, using pulse oximetry or a CRSS, with 4–6 hours of continuous sleep duration should be adequate for diagnosing moderate-to-severe SDB in children. The sleep duration is defined as continuous to allow adequate opportunity for all sleep stages to occur. Combining short episodes of sleep interspersed with wake to create 4–6 hours of sleep recording may miss parts of the sleep cycle and is not advised. This includes children under the age of 2 years, where rapid eye movement (REM) cycles are more evenly dispersed through the night. If a child is older than 2 years of age (when REM sleep is greater in the latter half of the night), or if mild disease is to be excluded, a period of longer than 6 hours is advised.

Pulse oximetry/CRSS optimal number of monitoring nights

Recommendation

► A single night of pulse oximetry monitoring, ideally consisting of 6 hours of continuous sleep duration, can be considered adequate for identifying SDB in children without comorbidities. (Conditional—by consensus)

Good practice points

✓ A single night of CRSS monitoring should also be considered adequate for identifying SDB in children without comorbidities.

✓ If it is anticipated that a child will poorly tolerate a pulse oximetry probe, consider providing a pulse oximeter for more than one night to acquire at least one night of technically adequate data. Alongside the sleep log data, information on how typical the period of sleep was for the child should also be collected.

✓ If pulse oximetry or CRSS is being considered for diagnosing SDB in children with comorbidities more than one night of monitoring should be considered, particularly if a parent/carer reports that an initial period of monitoring is not representative of the child's sleep.

✓ If a CRSS is normal but symptoms are ongoing, a repeat CRSS should be performed.

CO_2 monitoring and pulse oximetry for monitoring home ventilation

Good practice points

✓ If children are receiving continuous positive airway pressure (CPAP) therapy or bilevel positive airway pressure (BiPAP) therapy, regular monitoring should be provided with a minimum of pulse oximetry and CO_2 monitoring.

✓ When deciding on which type of sleep study to perform, the relative risks and benefits of each should be discussed with the patient and/or carer.

✓ Data download from a CPAP device or ventilator can help complement results from a sleep study, but operators should note that many ventilator algorithms, such as AHI, have not been validated in children.

Narcolepsy

Recommendations

► If SDB is excluded, or effectively treated, and excessive daytime sleepiness (EDS) persists, other diagnoses including narcolepsy, with possible coexistent cataplexy, sleep paralysis, hypnagogic and hypnopompic hallucinations and circadian rhythm disorders should be considered. (Conditional—by consensus)

► As cataplexy may be subtle, both child and parents/carers should be asked about head nods, neck/shoulder posturing and eyelid/facial droop. These are typically associated with laughter but may also be associated with anger or frustration. (Conditional—by consensus)

► Both child and parents/carers should be asked about sleep paralysis, hypnagogic and hypnopompic hallucinations. (Conditional—by consensus)

► Both child and parents/carers should be asked about sleep onset and wake up times to elicit total sleep time and sleep latency to exclude a circadian rhythm disorder that can be associated with EDS. (Conditional—by consensus)

Good practice points

✓ An awareness of rare conditions in children, which may primarily present with EDS, should always be maintained.

✓ As the associated symptoms of narcolepsy may be subtle or may not be volunteered, directed questions in the clinical history should be used to elicit a possible diagnosis of narcolepsy in children and initiate referral to a specialist paediatric sleep service for specialist assessment and investigation. The current standard of diagnostic investigation is a 1-week period (minimum, preferably 2 weeks) of actigraphy with PSG and multiple sleep latency testing (MSLT). These investigations should be performed in line with AASM/European Sleep Research Society (ESRS) guidance.[5 6]

✓ Children with narcolepsy should be under the care of a clinician with special expertise in the management of narcolepsy. This may be a paediatric neurologist or a sleep physician depending on local service arrangements.

Sleep assessments for children undergoing tonsillectomy

Recommendations

► Routine preoperative sleep monitoring as a basis for surgical decision-making is not recommended in children without comorbidities who are over the age of 2 years, and in whom severe OSA is not suspected. (Conditional—by consensus)

► Preoperative sleep monitoring before tonsillectomy (with or without adenoidectomy) should be considered for children who are less than 2 years of age to allow preoperative planning. (Conditional—by consensus)

Good practice points

✓ Preoperative sleep monitoring before tonsillectomy (with or without adenoidectomy) may be considered for children of all ages with comorbidities (eg, obesity, Down syndrome, cerebral palsy, neuromuscular disease) and suspected SDB to confirm a diagnosis of SDB and allow preoperative planning.

✓ A preoperative pulse oximetry sleep study before tonsillectomy (with or without adenoidectomy) may be considered for children without comorbidities with suspected severe OSA.

✓ Sleep monitoring following tonsillectomy (with or without adenoidectomy) may also be considered for children with severe OSA, with or without comorbidities, if there is a clinical need (eg, less than 2 years of age, Down syndrome, obesity, cerebral palsy, neuromuscular disease).

INTRODUCTION

Aim of the guideline

The guideline aims to provide clarification on the use of diagnostic tools and recordings in the diagnosis and monitoring of children with SDB. The techniques include sleep questionnaires, sleep video recording, sleep audio recording, pulse oximetry (with or without CO_2 monitoring) and CRSS. The guideline will provide important information on the:

1. Basic principles behind the different technologies, including evidence on the benefits of artefact-excluding oximeters.
2. Technical and patient considerations to be borne in mind when arranging different investigations to ensure that the data obtained are of adequate quality, including the limitations of the different types of study.
3. Indications for different types of sleep study, for example, when is a more complex investigation (eg, CRSS) justified over simpler pulse oximetry. Specific advice will be given for children who are at high risk of SDB problems.
4. Diagnostic criteria for abnormalities on sleep studies based on the AASM guidelines[3] and age-specific normal reference ranges.
5. Issues around appropriate service provision in a UK National Health Service (NHS) context.

The guideline will make use of existing evidence and where this is absent, consensus from the guideline committee will be obtained to provide guidance on the above.

Intended users of the guideline and target patient populations

The guideline will be of interest to clinicians caring for children with SDB including paediatric respiratory physicians, general paediatricians, paediatric respiratory nurses, paediatric physiotherapists, sleep physiologists, paediatric neurologists, otorhinolaryngologists, other allied health professionals and patients and carers.

Scope of the guideline

The guideline will focus on how investigative techniques are best used within the NHS to diagnose and monitor children (0–16 years) with SDB. An overview will be provided on the use of sleep studies to investigate SDB and will focus on sleep diagnostics for groups of children with, or without comorbidities rather than on specific diseases such as cyanotic congenital heart disease, bronchopulmonary dysplasia (BPD) and Prader Willi syndrome.

Areas not covered by the guideline

The guideline focuses on the broader field of SDB and does not focus on specific sleep disorders, such as OSA, as alternative guidance is already available (European Task Force, Obstructive SDB in children aged 2–18 years: diagnosis and management, 2015[7] and the European Respiratory Society statement on obstructive SDB in children aged 1–23 months, 2017[8]). However, please note that where the supporting evidence for individual clinical questions was lacking, some evidence reviews may be focused on OSA.

Recommendations will not be made on techniques that are not widely available within the UK.

Limitations of the guideline

Healthcare providers need to use clinical judgement, knowledge and expertise when deciding whether it is appropriate to apply recommendations for the management of patients. The recommendations cited here are a guide and may not be appropriate for use in all situations. The guidance provided does not override the responsibility of healthcare professionals to make decisions appropriate to the circumstances of each patient, in consultation with the patient and/or their guardian or carer.

Members of the guideline development group

The guideline development group (GDG) was chaired by two paediatric respiratory consultants, Dr Hazel Evans (HE) and Dr Neil Gibson (NG). The GDG had a wide membership and included colleagues from paediatric respiratory medicine, general paediatrics, sleep physiology, specialist paediatric nursing, ear, nose and throat (ENT) surgery and paediatric neurology. Two patient representatives were recruited to the group, but due to personal circumstances both had to withdraw before completion of the guideline (February 2020 and January 2021). However, a further patient representative was recruited at the end of the guideline process to review the final guideline and provide the parent/carers' perspective. Those on the group were not required to be BTS members and a full list of members can be seen in Appendix 2.

METHODOLOGY OF GUIDELINE PRODUCTION

Establishment of GDG

The GDG was convened in July 2018, with the first meeting taking place in October 2018. The full GDG met five times during the development of the guideline and kept in close contact by teleconference and email throughout the process.

Methodology

This BTS guideline uses Grading of Recommendations, Assessment, Development and Evaluation (GRADE) methodology in the guideline development process. Full details are provided in the BTS Guideline production manual (https://www.brit-thoracic.org.uk/quality-improvement/guidelines/).

Summary of key questions, outcomes and literature search

Clinical questions were defined from the scope of the guideline and formulated into PICO-type (population, intervention, comparator and outcome) framework diagnostic accuracy, intervention or prognostic review formats. A full list of clinical questions for each section of the guideline is provided in Appendix 3.

Patient centred outcomes were agreed by the group for each question.

The PICO framework formed the basis of the literature search. The initial searches were completed by the University of York, and latterly by BTS Head Office. Systematic electronic database searches were conducted to identify all papers that may be relevant to the guideline. For each question, the following databases were searched: Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE and EMBASE. The search strategy is available for review in online supplemental appendix 12.

Literature review

Two literature searches were conducted for the guideline, with the number of resulting abstracts from each search shown in table 1:

Letters, conference papers and news articles were removed and criteria for initial screening of the abstracts were:

- Does the study type match the study type criteria in the clinical question protocols?
- Does the population match the clinical question population(s)?
- Is the abstract in English?

Table 1 Literature search details

Search number	Date	Number of abstracts
1	20 February 2019	2234
2	18 March 2021	522

The remaining abstracts were screened by HE and NG and potentially relevant abstracts allocated to the relevant clinical questions. Abstracts were not rejected based on the journal of publication, authorship or country of origin.

GDG members were allocated to work on individual questions in small groups. Each abstract was read and at least two members agreed whether the abstract was 'potentially relevant' or 'not relevant' to the clinical question of interest. Abstracts were excluded if they were deemed 'not relevant' to the clinical question.

Full papers were obtained for all abstracts assigned as 'potentially relevant'. Each full paper was reviewed to assess if it addressed:

1. The clinical question population.
2. The index test and reference standard (for diagnostic accuracy questions), the intervention and comparator (for intervention questions), or the exposure and referent (for prognostic questions).
3. The study type(s) defined in the clinical question protocol.
4. The clinical question outcome(s).

Each full paper fulfilling the above criteria, and agreed by at least two members of the GDG, was 'accepted' for meta-analysis and subsequent critical appraisal.

In circumstances where there was little, or no supporting evidence that fulfilled the above criteria, the full paper inclusion strategy was widened to include evidence that partially addressed the clinical question.

The second literature search (Search 2) was undertaken in March 2021 (table 1) to capture additional published evidence while the guideline was in development prior to finalising the draft document. The additional abstracts were reviewed and allocated to the clinical questions as above.

The full list of abstracts has been retained and is kept in an archive.

Systematic review of the evidence

Each 'accepted' full paper underwent a systematic review. Data were extracted and meta-analyses were performed for each clinical question on an outcome-by-outcome basis for intervention reviews, or an index test basis for diagnostic accuracy reviews. If meta-analysis was not possible, because there was insufficient evidence to perform a meta-analysis, or if data could not be extracted to input into a meta-analysis, or data across studies had been published in different formats, all relevant supporting data were tabulated where possible.

All full papers contributing towards a meta-analysis underwent critical appraisal. For all non-meta-analysed data included in an evidence review, contributing papers also underwent critical appraisal where possible.

All meta-analyses and risk of bias assessments (critical appraisal) were performed in Review Manager V. 5.3 and agreed by at least two members of the GDG. Papers no longer deemed relevant were removed from the systematic review, with the decision to 'exclude' a paper solely based on it not fulfilling the clinical question criteria.

Table 2 Evidence statement (GRADE) score definitions

Grade		Definition
High	⊕⊕⊕⊕	High confidence that the true effect is close to the estimated effect
Moderate	⊕⊕⊕◯	Moderate confidence that the true effect is close to the estimated effect
Low	⊕⊕◯◯	Low confidence that the true effect is close to the estimated effect
Very low	⊕◯◯◯	Very low confidence that the true effect is close to the estimated effect
Ungraded		GRADE analysis not possible, but evidence deemed important by the GDG

GDG, guideline development group; GRADE, Grading of Recommendations, Assessment, Development and Evaluation.

GRADE analysis of the evidence

Having generated evidence profiles for each of the clinical questions, GDG question groups assessed the quality of the evidence using the GRADE methodology.[9–14]

Where GRADE analysis was not possible, but GDG members felt the evidence was important to be included in the Evidence Statements, these have been listed as (Ungraded). Definitions of the Evidence statement (GRADE) scores are shown in table 2.

Each clinical question was reviewed by the full GDG during the regular meetings and consensus was reached in relation to the evidence summary.

Development of recommendations

The GDG proceeded to decide on the direction and strength of recommendations considering the quality of the evidence, the balance of desirable and undesirable outcomes and the values and preferences of patients and others. GRADE specifies two categories of strength for a recommendation, as shown in table 3.

From the outset, it was acknowledged that there would be little high-quality evidence for some of the clinical questions identified. In this instance, low-grade evidence was considered, along with the expert opinion of the GDG, via informal consensus at the meetings.

Good Practice Points (GPPs) were also developed by informal consensus in areas where there was no quality evidence but the GDG felt that some guidance, based on the clinical experience of the GDG, might be helpful to the reader. These are indicated as shown below.

✓ Advised best practice based on the clinical experience of the GDG

In some instances where evidence was limited, but GDG members felt that it was important to include a recommendation rather than a GPP, recommendations were agreed by informal consensus and categorised as (Conditional—by consensus), based on the same criteria detailed in table 3.

Information on the consensus method is available at https://www.brit-thoracic.org.uk/quality-improvement/guidelines/sleep-disordered-breathing-in-children/.

Cost-effectiveness was not considered in detail as in-depth economic analysis of recommendations falls outside of the scope of the BTS guideline production process. However, the GDG were asked to be mindful of any potential economic barriers to the implementation of recommendations and GPPs.

Research recommendations were also identified (available in online supplemental appendix 13).

Table 3 Explanation of the terminology used in BTS recommendations

Strength	Benefits and risks	Implications
Strong Recommended, so 'offer'	Benefits appear to outweigh the risks (or vice versa) for the majority of the target group	Most service users would want to, or should receive this intervention
Conditional Suggested, so 'consider'	Risks and benefits are more closely balanced, or there is more uncertainty in likely service users' values and preferences	Service users should be supported to arrive at a decision based on their values and preferences

Drafting the guideline

The GDG corresponded regularly by email, and meetings of the full group were also held in the period between October 2018 and November 2021. The BTS Standards of Care Committee (SOCC) reviewed the draft guideline in September 2020 and September 2021. A revised draft guideline document was circulated to all stakeholders for consultation in March 2022, followed by a period of online consultation.

Review of the guideline

The guideline will be reviewed 5 years after the date of publication.

Stakeholders

Stakeholders were identified at the start of the process. All stakeholder organisations were notified when the guideline was available for public consultation and a list is published in Appendix 4.

Online supplemental appendices

All online supplementary appendices are also available via the BTS website (https://www.brit-thoracic.org.uk/quality-improvement/guidelines/sleep-disordered-breathing-in-children/).

INTRODUCTION TO PAEDIATRIC RESPIRATORY SLEEP DISORDERS

Paediatric sleep disorders are commonly divided into those that compromise breathing (SDB) and those occurring because of neurological or psychological abnormalities. This guideline will focus on SDB, which affects between 2% and 11% of children, and causes a range of problems for children, including sleep disruption, educational and cognitive impairment, behavioural problems; and for children with comorbidity, recurrent respiratory illness, hospital admissions and death.[15–17]

Children referred for SDB

SDB in children is commonly divided into:

- Breathing abnormalities related to snoring and upper airway obstruction that are found in otherwise typically developing children (commonly referred to as OSA).
- More complex findings that are found in children with underlying conditions, including, genetic disorders, neurodevelopmental and neuromuscular disorders, metabolic disease, craniofacial and skeletal disorders.

Children with underlying conditions may have breathing problems relating to central nervous system dysfunction, bulbar and respiratory muscle disorders, rib and spinal deformity or lung and lower airway problems (including restriction from obesity). Commonly, the breathing abnormalities in these children are multifactorial and may include OSA as found in otherwise healthy children.

One of the largest cohorts of children who might be considered for investigations of SDB are children referred for consideration of ENT surgery due to symptoms of OSA (Box 1).

The primary indication for sleep investigations is to provide diagnostic certainty, but sleep investigations are also used to estimate the likelihood of additional risks associated with surgery. The validity for this is unclear.

Children with underlying conditions are primarily referred with one or more symptoms of SDB, but also because they may have poor growth, disturbed sleep, delayed development or education, nocturnal or poorly controlled seizures, or to assess the risks for anaesthesia and surgery. While SDB is common in some of these groups (eg, 50%–100% of children with Down Syndrome),[15 18] we are still learning which diagnostic tests provide the best information for managing this group of children and what thresholds should trigger interventions.

A small proportion of children are also referred to paediatric services with daytime hypersomnolence having had SDB excluded (Box 2). It is important that clinicians are aware of potential diagnoses to be considered in this instance and have an appropriate referral and investigation pathway. Hence, this guideline will also explore clinical features that are associated with a diagnosis of narcolepsy.

Diagnostic techniques for diagnosing SDB in children

The investigation and management of children with SDB has developed rapidly in the UK over the last 20 years. However, there is a degree of varied practice and inconsistency in service provision. This guideline aims to provide clarity on the most appropriate way to investigate these children. This will help clinicians working with families and also guide the ongoing development of sleep services within the NHS.

In the UK, there are a range of investigative techniques available to paediatricians and ENT surgeons. These include validated symptom questionnaires and overnight sleep studies, which

Box 1 Features of obstructive sleep apnoea

Snoring
Loud inspiratory gasps
Increased effort breathing, chest caving in
Head extension
Mouth breathing
Dry mouth, thirst, halitosis
Restlessness, recurrent arousals
Waking tired in the morning
Daytime tiredness
Impaired concentration during the day
Challenging behaviour
Odd sleep positions
Choking or gagging in sleep
Morning headaches
Difficult to control, or worsening of epilepsy
Poor growth
Right heart strain or pulmonary hypertension

Box 2 Causes of excessive daytime somnolence

Lack of sleep
⇒ Chronic medical disorder (eg, itch, pain, cough, polyuria seizures).
⇒ Poor sleep hygiene/environment.
⇒ Depression/anxiety disorder.

Poor quality sleep
⇒ Sleep-disordered breathing.
⇒ Restless legs syndrome including periodic limb movement disorder.
⇒ Seizures.
⇒ Cerebral event/injury.

Shifted sleep
⇒ Sleep wake phase disorder.

Primary sleep disorder
⇒ Narcolepsy.
⇒ Klein Levin syndrome.
⇒ Primary hypersomnia.

range in their complexity. This review will aim to determine whether sleep questionnaires and/or sleep investigation Types 2–4 (table 4 and definition table 5) offer an acceptable level of diagnostic accuracy when compared with PSG, commonly accepted as the gold standard. In addition, the guideline will also explore whether sleep studies undertaken at home provide acceptable diagnostic accuracy when compared with those undertaken in hospital.

While full PSG is commonly considered the best diagnostic test, it is more complex and costly than other recording modalities, and as such mostly needs inpatient facilities. It is not easily applied in the home, or for recording breathing in the daytime, or while mobile, which are sometimes needed in children with underlying conditions. It provides information on gas exchange, heart and respiratory rates, respiratory events, sleep stages and arousals, including those related to respiratory events. Because of demand, cost, limited expertise and the need for mobility or home studies, simpler techniques have become increasingly sought. This guideline reviews these proxy methodologies alongside PSG.

The most commonly used measure of severity of SDB is the apnoea hypopnoea index (AHI) (see 'Measuring SDB in children for information on how AHI is measured' section). This index was primarily developed for adults, then modified for use

Table 4 Types of sleep study

Sleep study type	Synonyms	Features	Key diagnostic measures	Strengths	Weaknesses
Type 1					
Inpatient polysomnography (PSG)	Full sleep study Full PSG	EEG, EOG, EMG, ECG Full set of respiratory measures Position and movement sensors Video and audio ± CO_2	Sleep staging Sleep duration Arousal frequency AHI, OAHI & CAHI SpO_2 measures (see table 5) ± CO_2 measures (see table 5)	Allows detailed characterisation of sleep stages including timing and quantity of REM, fragmentation and the sleep hypnogram. Regarded as the gold standard	Normally inpatient investigation, intrusive for patient, labour-intensive and expensive
Type 2					
Cardiorespiratory sleep study (CRSS)	Limited channel study Cardiorespiratory polygraphy	Similar to PSG but without EEG, EOG or EMG Measures a minimum of respiratory effort, airflow, SpO_2 and heart rate/ ECG ± video, ± CO_2	AHI, OAHI and CAHI SpO_2 measures ± CO_2 measures	Simpler for staff and patient	Intrusive for patient Sleep stages assessed indirectly from heart rate and breathing patterns ± video
Type 3					
Unattended polygraphic study (Home PSG or home CRSS)	Home sleep study	Normally fewer signal channels than PSG or CRSS Minimum of respiratory effort, airflow SpO_2, ± video, ± CO_2	AHI, OAHI, CAHI, SpO_2 measures ± CO_2 measures	No need for inpatient stay	Studies often reliant on set-up and running by a parent or carer, intrusive for patient Sleep assessed as for Type 2
Type 4					
Single or dual parameter monitoring (pulse oximetry ± continuous CO_2)	Saturation study/gas exchange study	Assessment of pulse and estimated SpO_2 ± CO_2	SpO_2 measures ± CO_2 measures	Simple, published normal ranges for data	Only 1–2 parameters to allow interpretation. CO_2 monitoring – CO_2 sensors expensive and fragile. Sleep can only be estimated from heart rate. Oxygen desaturations non-discriminatory between obstructive and central events

AHI, Apnoea Hypopnoea Index; CAHI, Central Apnoea Hypopnoea Index; CO_2, carbon dioxide; EEG, electroencephalogram; EMG, electromyogram; EOG, electrooculogram; OAHI, obstructive apnoea hypopnoea index; REM, rapid eye movement; SpO_2, oxygen saturation.

Table 5 Parameters from oxygen saturation (SpO_2) and carbon dioxide (CO_2) signals

SpO_2	CO_2
Mean/median	Mean/median
Range/fifth & 95th centiles	Range/fifth & 95th centiles
Nadir	Peak
>3% and >4% Oxygen desaturation index (ODI3, ODI4) and mean desaturation nadir	Time and % of study where CO_2 >6.7 kPa/ 50 mm Hg
Time and % of study where SpO_2 <95%, 90%, etc.	Changes with REM/active sleep
Changes with REM/active sleep	
Mean desaturation nadir - average of the minimum saturation resulting from desaturations from baseline. REM, rapid eye movement.	

in children and has been shown to improve with intervention. However, the evidence linking AHI values in children to functional outcomes is sparse, especially in children with underlying conditions, hence clinicians are cautioned from using AHI alone to guide decision-making.

A brief description of each investigative technique is also provided below.

Paediatric sleep questionnaires

Sleep questionnaires are a collection of two or more questions, assessed for their ability to discriminate between those with or without SDB, and validated in a particular reference group of children. Their appeal is their relative ease of use, low cost and wide accessibility compared with other tools detailed in table 4. Sleep questionnaires are designed to identify the most discriminatory components of a child's sleep history, and responses often require analysis with a scoring algorithm. The SRBD scale of the PSQ (SRBD-PSQ) and OSA-18 item questionnaires (OSA-18) are the two most studied questionnaires, but several others have been studied.

Sleep questionnaires can also be combined with a clinical assessment, where the findings from a protocol-driven clinical examination are combined with the questionnaire responses. Two examples are the SCR and the CAS-15 questionnaires. The SCR is reported to take about 30 min to complete, which is likely to limit its usefulness in a clinical context. In contrast, the CAS-15 is a simpler assessment based on scores from 15 items, 10 of which are acquired by clinical history and 5 from a physical examination, and is much shorter than the SCR, reportedly only taking 10 min to complete.

Sleep questionnaires and sleep questionnaires with a 'protocol-driven' clinical examination have been evaluated separately in the guideline (see 'Sleep questionnaires, combined sleep questionnaires and clinical assessment, sleep video recording and sleep audio recording' sections and online supplemental appendix 1).

Paediatric sleep video recordings

Sleep audio-visual recordings are commonly obtained as a component of multichannel-sleep studies (table 4, types 1–3) but could also be used as a single modality, for a defined minimum duration and specified format, for their ability to identify periods of sleep that are suggestive of SDB. This is usually based on the presence of snoring, obstructed breathing, increased effort of breathing, presence of apnoea and associated arousals. The videos are analysed against pre-specified scoring criteria to determine the presence or absence of SDB. Sleep video recordings are considered in the 'Sleep questionnaires, combined sleep questionnaires and clinical assessment, sleep video recording and sleep audio recording' sections and online supplemental appendix 1.

Paediatric sleep audio recordings

Sleep audio recordings are also commonly obtained routinely as a component of multichannel sleep studies (table 4, types 1–3) but could also be used as a single modality for a defined minimum duration and format, for their ability to identify breathing sounds that are suggestive of SDB. This would be expected to include periods of snoring and/or periods when a child sounds as though they are struggling to breathe. The sound recording would typically be scored against pre-specified criteria designed to determine the presence or absence of SDB. Sleep audio recordings are also considered in the 'Sleep questionnaires, combined sleep questionnaires and clinical assessment, sleep video recording and sleep audio recording' sections and online supplemental appendix 1.

Pulse oximetry

Pulse oximetry is used to estimate oxygen levels (SpO_2) in the blood and has been considered as a low-cost screening method for diagnosing SDB in children (see 'Pulse oximetry and cardiorespiratory sleep studies' sections and online supplemental appendix 2 (children without comorbidities) and online supplemental appendix 4 (children with comorbidities)). There are a range of pulse oximeters available, with different internal algorithms for data analysis. They provide an output for real-time data collection or have internal memories that allow downloads of peripheral capillary SpO_2 (which acts as a surrogate for arterial SpO_2), plethysmographic and heart rate data. More recently, algorithms with motion artefact rejection properties have also been integrated into many oximeters that are used in paediatric clinical services in the UK. It is unclear whether these properties offer improved diagnostic accuracy for SDB, or whether the diagnostic accuracy of this investigation is impacted by either the length of the period of sleep monitoring or settings within the oximeter such as averaging time (specific window of time over which an average SpO_2 value is estimated). This is also included within the guideline (see 'Pulse oximetry motion artefact removal and averaging time', 'Optimal monitoring time for pulse oximetry and CRSS' and 'Is one night of pulse oximetry or CRSS monitoring enough?' sections and online supplemental appendix 5, online supplemental appendix 6 and online supplemental appendix 7 respectively).

CO_2 monitoring

CO_2 monitoring, or capnography, monitors the partial pressure of CO_2 in exhaled air via an end-tidal device (end-tidal capnography), or the diffusion of CO_2 into transcutaneous sensors applied on the skin (transcutaneous capnography). Transcutaneous capnography provides a constant, slow-changing measurement through the night, but is an expensive technology requiring care in sensor placement. In contrast, end-tidal capnography is simpler and cheaper, providing breath-by-breath measurements, but commonly the signal is absent due to poorly tolerated or misplaced flow sensors (see 'Pulse oximetry and CO_2 monitoring' sections and online supplemental appendix 3).

Cardiorespiratory sleep studies

CRSS measure physiological parameters which focus on breathing and gas exchange. This level 2 study type (table 4)

measures oximetry, airflow, thoracoabdominal respiratory effort and ECG. Additional modalities may include CO_2 monitoring, movement, body position, snoring and audio/video recording. Sleep staging cannot be achieved with a level 2 study, however parameters recorded in this study type can provide physiological estimates of sleep/wake patterns as well as quiet and active sleep. CRSSs are commonly used in the UK to investigate paediatric SDB, in particular to determine if the aetiology of the SDB is central or obstructive in pattern (see 'Pulse oximetry and cardiorespiratory sleep studies' sections and online supplemental appendix 2 (children without comorbidities) and online supplemental appendix 4 (children with comorbidities)).

Polysomnography

PSG is considered the gold standard for diagnosing SDB and measures a wide range of modalities including oximetry, airflow, respiratory effort (thorax and abdomen), ECG, electroencephalogram (EEG), electrooculogram and electromyogram. Thus, it provides information on gas exchange, heart and respiratory rates, respiratory events, sleep stages and arousals, including those related to respiratory events. PSG is an expensive resource used predominantly on inpatients with attendant physiologists or trained healthcare assistants and requires a high level of expertise to interpret the findings. It is not easily applied in the home, or for recording breathing in the daytime or while mobile, a facility sometimes needed in children with underlying conditions.

Measuring SDB in children

As a result of types 1 and 2 recordings (table 4), SDB conditions are commonly categorised by the dominant type of breathing disturbance into OSA and central (or non-obstructive) sleep apnoea (CSA). Respiratory events are classified according to the AASM. In children under 16 years of age apnoeas are defined as a ≥90% reduction in airflow for ≥2 breaths. Apnoeas with continued respiratory effort are classified as obstructive apnoeas, whereas apnoeas with cessation of respiratory effort and an associated ≥3% SpO_2 desaturation or EEG arousal are classified as central apnoeas. In addition, hypopnoeas are classified by the AASM as a ≥30% reduction in airflow for ≥2 breaths in association with a ≥3% SpO_2 desaturation or EEG arousal.[3] These respiratory events are then expressed as an index of events per hour averaged out over the entire night (the AHI).[19] Commonly used criteria for OSA in children are mild, moderate and severe with the corresponding obstructive AHI (OAHI) cut-off values defined in table 6. Similarly, in children over the age of two, the criterion for CSA is a central AHI (CAHI) ≥5 (table 6).

Please note that some studies referenced in this guideline have referred to OSA data as 'OAHI' while others use 'AHI'. Due to the lack of available evidence, it was not possible to perform subgroup analyses on 'OAHI' and 'AHI' data separately, so all relevant data (OAHI and AHI) have been included in the analyses and are referred to as 'AHI' unless otherwise stated.

OSA and CSA are associated with adverse respiratory and neurocognitive outcomes, with evidence of a dose effect, although there is some debate as to the degree of reversibility that exists.[15 16 20–22] Children with a significant degree of SDB are also generally at increased risk of death, although this is more likely to be related to the underlying condition in most.[17] Interventions for OSA and CSA may also have adverse effects with a very small mortality risk associated with adenotonsillectomy[23] and also a potential for harm from the use of positive pressure support. Therefore, it is imperative that children suspected of having SDB have access to investigations of sufficiently high diagnostic accuracy to inform clinical management.

Table 6 Apnoea Hypopnoea Index (AHI) criteria for obstructive sleep apnoea (OSA) and central sleep apnoea (CSA) in children under 16 years of age[7 16] and children of 16 years of age or older[32 33]

Sleep apnoea type	AHI criteria	
	<16 years old	≥16 years old
Mild OSA	OAHI ≥1 and <5	AHI ≥5 to <15
Moderate OSA	OAHI ≥5 and <10	AHI ≥15 to <30
Severe OSA	OAHI ≥10	AHI ≥30
CSA	CAHI ≥5 (2–15 years of age)	

AHI, Apnoea Hypopnoea Index; CAHI, Central Apnoea Hypopnoea Index; OAHI, Obstructive AHI.

Diagnostic test accuracy reviews

Diagnostic test accuracy reviews evaluate how good, or bad, a diagnostic test is for diagnosing a disease and have been used for several clinical question reviews within the guideline. Test accuracies are usually reported as sensitivity and specificity and commonly labelled as 'very high', 'high', 'moderate' or 'low', but currently there is no standard definition of what each level is. Hence, for the purposes of this guideline the definitions in table 7 have been used (cut-offs not validated). It is important when considering implementation of the recommendations to consider the prevalence of the condition within the clinical setting. This will affect the positive and negative predictive values of a test, that is, the proportion of patients with a positive or negative test who are correctly diagnosed.

DIAGNOSIS

In the UK, resources, inpatient bed capacity and availability of expertise have limited the use of PSG, with clinicians tending to prefer simpler investigative techniques to detect SDB wherever possible. This allows recordings that could ideally be undertaken in primary or secondary care, or even at home, but the choice of diagnostic test used is likely to be impacted by the presence or absence of comorbidities. Hence, when a child first presents with SDB, it is important to take a brief clinical history to direct the healthcare provider towards the correct recommended pathway for diagnosing SDB. This assessment should also consider the type and location of investigation that is likely to be tolerated by the child and family. The recommended diagnostic approaches for diagnosing SDB in children without, or with comorbidities are described in the 'Children without comorbidities' and 'Children with comorbidities' sections. The diagnostic tests discussed in this document (sleep questionnaires, combined sleep questionnaires and clinical assessment, sleep video recording, sleep audio recording, pulse oximetry and CRSS) have been compared with the accepted gold standard test of PSG.

Children without comorbidities

For children without comorbidities there are a number of cost-effective diagnostic techniques that are used to diagnose SDB. These include sleep questionnaires, sleep video recordings, sleep audio recordings, pulse oximetry and CRSS, so the first clinical questions were:

> Q1 What is the diagnostic accuracy of using a sleep questionnaire, a combined sleep questionnaire and 'protocol-driven' clinical assessment, a sleep video recording or a sleep audio recording to identify SDB in children with suspected SDB?

Table 7 Guideline definitions of 'very high', 'high', 'moderate' and 'low' sensitivity/specificity

Level	Pooled estimate sensitivity/specificity
Very high	90% to 100%
High	>80% to 90%
Moderate	65% to 80%
Low	<65%

Q2 For children with suspected SDB, what is the diagnostic accuracy of pulse oximetry and CRSS?

Q3 For children undergoing investigation for SDB, does CO_2 monitoring with pulse oximetry improve clinical outcomes, when compared with pulse oximetry alone?

Sleep questionnaires, combined sleep questionnaires and clinical assessment, sleep video recording and sleep audio recording

Q1 What is the diagnostic accuracy of using a sleep questionnaire, a combined sleep questionnaire and "protocol driven" clinical assessment, a sleep video recording or a sleep audio recording to identify SDB in children with suspected SDB?

Summaries of the sleep questionnaire meta-analyses data (which were reported in ≥2 studies) and the combined sleep questionnaire and 'protocol-driven' clinical assessment meta-analyses data are shown in tables 8 and 9 respectively (taken from online supplemental appendix 1, tables 1b and 1c) and the resulting Evidence Statements and Recommendation from Q1 are presented below. The full evidence review is presented in online supplemental appendix 1. Please note that children with comorbidities were also considered as a subgroup in this question, but all relevant Evidence Statements, Recommendations and GPPs concerning children with comorbidities are presented in the 'Children with comorbidities', 'Sleep questionnaires, combined sleep questionnaires and clinical assessment, sleep video recording and sleep audio recording' section.

Evidence statements

- Sleep questionnaires appear to have a moderate sensitivity and low specificity for diagnosing SDB in children. (Very low)
- SRBD scale of the PSQ (SRBD-PSQ), with a cut-off of ≥0.33, appears to have a high sensitivity and low specificity for diagnosing moderate-to-severe SDB (AHI ≥5) in children. (Low)
- The OSA-18 item questionnaire (OSA-18), with a cut-off of ≥0.60, appears to have a moderate sensitivity and low specificity for diagnosing moderate-to-severe SDB (AHI ≥5) in children. (Low)
- There was not enough evidence to make specific considerations on the use of sleep questionnaires for children under 2 years of age.
- There was not enough evidence to make a consideration on sleep video recording or sleep audio recording to diagnose SDB in children.
- Sleep questionnaires and 'protocol-driven' clinical assessment appear to have a high sensitivity and a low specificity for diagnosing SDB in children. (Low)

Recommendations

- ► SRBD scale of the PSQ (SRBD-PSQ), with a cut-off of ≥0.33, or OSA-18 item questionnaire (OSA-18), with a cut-off of ≥0.60, can be considered for diagnosing moderate-to-severe SDB in children of at least 2 years of age with no comorbidities. If a test questionnaire is inconsistent with clinical features, or if a higher degree of diagnostic certainty is required, further tests such as pulse oximetry, CRSS or PSG are recommended. (Conditional)
- ► Sleep questionnaires combined with a 'protocol-driven' clinical assessment can be considered for diagnosing SDB in children, but it should be noted that the SCR is labour-intensive, taking approximately 30 min to complete. If a test questionnaire is inconsistent with clinical features, or if a higher degree of diagnostic certainty is required, further tests such as pulse oximetry, CRSS or PSG are recommended. (Conditional)

Good practice points

- ✓ Clinical questionnaires, combined with clinical examination, can identify moderate or severe SDB with a moderate-to-high sensitivity and low-to-moderate specificity. This may be considered adequate, for example, in relation to deciding whether, or not to pursue surgery to improve the airway, (eg, tonsillectomy).

Table 8 Diagnostic accuracies of individual sleep questionnaires and cut offs for diagnosing sleep-disordered breathing in children without comorbidities reported in ≥2 studies

Questionnaire/cut-off	Number of datasets	Number of subjects	Sensitivity (95% CI)	Specificity (95% CI)
All data				
SRBD-PSQ (cut-off ≥0.33)	10	824	0.78 (0.72 to 0.83)	0.46 (0.37 to 0.56)
OSA-18 (cut-off ≥60)	10	1327	0.69 (0.56 to 0.80)	0.53 (0.42 to 0.64)
AHI ≥1				
SRBD-PSQ (cut-off ≥0.33)	5	410	0.75 (0.68 to 0.80)	0.55 (0.42 to 0.68)
OSA-18 (cut-off ≥60)	4	542	0.54 (0.49 to 0.59)	0.66 (0.46 to 0.82)
AHI ≥5				
SRBD-PSQ (cut-off ≥0.33)	3	255	0.84 (0.72 to 0.91)	0.37 (0.29 to 0.46)
OSA-18 (cut-off ≥60)	3	392	0.77 (0.49 to 0.92)	0.43 (0.27 to 0.60)
AHI ≥10				
SRBD-PSQ (cut-off ≥0.33)	1	97	0.86 (0.68 to 0.96)	0.32 (0.22 to 0.45)
OSA-18 (cut-off ≥60)	2	176	0.69 (0.56 to 0.80)	0.53 (0.44 to 0.62)

AHI, Apnoea Hypopnoea Index; OSA-18, Obstructive sleep apnoea-18 item questionnaire; OSA, obstructive sleep apnoea; SRBD-PSQ, Sleep-Related Breathing Disorder scale of the Paediatric Sleep Questionnaire.

Table 9 Diagnostic accuracies of using a sleep questionnaire and clinical assessment to diagnose sleep-disordered breathing in children without comorbidities

Included data	Number of datasets	Number of subjects	Sensitivity (95% CI)	Specificity (95% CI)
All	6	1213	0.83 (0.70 to 0.91)	0.57 (0.49 to 0.65)
SCR ≥6.5*	4	890	0.86 (0.70 to 0.95)	0.53 (0.41 to 0.64)
CAS-15 ≥32†	2	323	0.71 (0.65 to 0.77)	0.63 (0.52 to 0.73)

*All studies in the SCR meta-analysis regarded AHI >1 as a positive diagnosis of SDB.
†Both studies in the CAS-15 meta-analysis regarded AHI >2 as a positive diagnosis of SDB.
AHI, Apnoea Hypopnoea Index; CAS, Cleveland adolescent sleepiness; SCR, sleep clinical record; SDB, sleep-disordered breathing.

✓ The CAS-15 combined sleep questionnaire and 'protocol-driven' clinical assessment may also be considered for diagnosing SDB in children. In contrast to the SCR, the CAS-15 takes 10 min to complete, but has a reduced sensitivity of moderate.
✓ Sleep questionnaires should not be considered for diagnosing SDB in children under 2 years of age, or if mild SDB is suspected.

Pulse oximetry and CRSS

Q2 For children with suspected SDB, what is the diagnostic accuracy of pulse oximetry and CRSS?

A summary of the pulse oximetry and CRSS meta-analyses results is shown in table 10 (taken from online supplemental appendix 2, table 2b) and the Q2 Evidence Statements, Recommendation and GPPs are presented below. The full evidence review is presented in online supplemental appendix 2. Please note that due to a lack of supporting evidence, some of the included studies had a mixed population within their study group (ie, children with and without comorbidities), or information on the inclusion of children with obesity, or lesser comorbidities was not provided. A summary of the 'Children without comorbidities' data is also provided in table 10.

Evidence statements

– Pulse oximetry appears to have a high sensitivity and moderate specificity for diagnosing SDB in children. (Very low)
– Pulse oximetry also appears to have a high sensitivity and low specificity for diagnosing moderate-to-severe SDB (Very low) and a very high sensitivity and moderate specificity for diagnosing severe SDB in children. (Very low)
– Based on very limited evidence (two studies), CRSS appear to have a moderate sensitivity and a very high specificity for diagnosing SDB in children. (Low)

Recommendation

► For children with suspected SDB, pulse oximetry can be considered as a first line diagnostic test for SDB. If a test result does not fit the clinical picture, a higher level of investigation, such as a CRSS, may be required (see also GPPs below). (Conditional)

Good practice points

✓ If pulse oximetry is normal, but there is suspicion of SDB, a CRSS may be useful to identify mild OSA. Sleep video recording may also be considered to give a clearer picture.
✓ If pulse oximetry is abnormal, CRSS are more specific and can discriminate between central and obstructive events.
✓ When analysing and interpreting paediatric pulse oximetry traces, an ODI4 cut-off of >4/hour and/or an ODI3 cut-off of >7/hour are suggestive of an abnormality in children over 2 years of age. Baseline mean SpO_2 of <95%, desaturations to <90% and clustering and depth of desaturation events should also be considered in pulse oximetry interpretation.[1 2] If one pulse oximetry parameter is considered abnormal when the other parameters are considered normal, a CRSS should be considered
✓ While pulse oximetry is non-discriminatory at all ages, particular caution is required in using oximetry to diagnose OSA in children under 2 years of age as children in this age group are predisposed to CSA (as a result of developmental

Table 10 Diagnostic accuracies of pulse oximetry and CRSS for diagnosing sleep-disordered breathing in children without comorbidities

Included data	Number of datasets	Number of subjects	Sensitivity (95% CI)	Specificity (95% CI)
Mixed population				
Pulse oximetry (all)	15	1704	0.82 (0.76 to 0.87)	0.75 (0.60 to 0.85)
Pulse oximetry (AHI ≥1)	6	894	0.81 (0.69 to 0.89)	0.83 (0.58 to 0.94)
Pulse oximetry (AHI ≥5)	5	617	0.81 (0.74 to 0.87)	0.62 (0.43 to 0.78)
Pulse oximetry (AHI ≥10)	3	218	0.95 (0.44 to 1.00)	0.72 (0.31 to 0.94)
CRSS (all)	5	410	0.76 (0.68 to 0.85)	0.96 (0.84 to 0.99)
CRSS (AHI ≥1)*	2	170	0.84 (0.76 to 0.89)	0.81 (0.67 to 0.90)
CRSS (AHI ≥5)	2	170	0.65 (0.52 to 0.76)	0.98 (0.89 to 1.00)
Children without comorbidities				
Pulse oximetry (all)	2	224	0.77 (0.59 to 0.90)	0.92 (0.36 to 1.00)
Pulse oximetry (AHI ≥1)	1	167	0.87 (0.77 to 0.93)	0.99 (0.94 to 1.00)
Pulse oximetry (AHI ≥5)	1	57	0.67 (0.46 to 0.83)	0.60 (0.41 to 0.77)

*Due to the lack of supporting evidence, one dataset with a cut-off value of AHI ≥1.5 was included in the CRSS (AHI ≥1) analysis.
AHI, Apnoea Hypopnoea Index; CRSS, Cardiorespiratory Sleep Study.

immaturity) and oxygen desaturations cannot discriminate between obstructive and central events.

✓ If a child is unable to tolerate CRSS equipment, for example children with autistic spectrum disorder, consideration should be given to using play therapy techniques to facilitate data acquisition. Consideration should also be given to undertaking CRSS in the home (see 'Home monitoring' section).

✓ If a CRSS test result does not fit the clinical picture, PSG should be considered (table 4). An exception to this is when CRSS rules out a diagnosis of SDB and a diagnostic pathway for narcolepsy should be considered (see 'Narcolepsy' section).

✓ Clinicians are cautioned from using AHI alone to guide decision-making.

✓ If hypoventilation is suspected, guideline users should refer to the 'Children without comorbididites, Pulse oximetry and CO_2 monitoring' section.

Pulse oximetry and CO_2 monitoring

The addition of CO_2 monitoring to pulse oximetry for diagnosing SDB in children has major implications in terms of adding complexity and cost, but there may be clinical situations when CO_2 monitoring might be of clinical value, so the next clinical question was:

> Q3 For children undergoing investigation for SDB, does CO_2 monitoring with pulse oximetry improve clinical outcomes, when compared with pulse oximetry alone?

Please note that due to a lack of direct evidence, diagnostic yield data was included in this review. The Q3 Evidence Statement and Recommendation are presented below and the full evidence review is presented in online supplemental appendix 3. Please also note that children with comorbidities were also considered as a subgroup in this question and all relevant Evidence Statements, Recommendations and GPPs concerning children with comorbidities are presented in the 'Children with comorbidities, Pulse oximetry and CO_2 monitoring' section.

Evidence statement

– The addition of CO_2 monitoring to pulse oximetry does not appear to increase the diagnostic yield of diagnosing SDB in children without comorbidities. (Ungraded)

Recommendation

► The addition of CO_2 monitoring to pulse oximetry is not recommended for diagnosing SDB in children without comorbidities. (Conditional—by consensus)

Children with comorbidities

Children with comorbidities who are predisposed to SDB encompass a broad range of conditions such as:

- Neuromuscular conditions.
- Nerve conduction disorders (e.g. Guillain-Barre syndrome, spinal cord injury).
- Disorders of central hypoventilation.
- Disorders with hypotonia.
- Disorders associated with airway patency predisposing to OSA.
- Disorders affecting secretion clearance leading to obstruction.
- Disorders resulting in obesity.
- Restrictive lung disorders' (skeletal dysplasias, scoliosis, costovertebral fusion).
- Interstitial lung disease.

The GDG, therefore, reviewed the use of sleep questionnaires, combined sleep questionnaires and clinical assessment, sleep video recording, sleep audio recording, pulse oximetry and CRSS for diagnosing SDB in children with comorbidities.

Sleep questionnaires, combined sleep questionnaires and clinical assessment, sleep video recording and sleep audio recording

Based on the evidence review of Q1 (see online supplemental appendix 1), there was currently not enough evidence to consider the use of sleep questionnaires for children with comorbidities. Hence, based on this lack of evidence, the use of sleep questionnaires for diagnosing SDB in children with comorbidities is not supported at this time.

Pulse oximetry and CRSS

Children with comorbidities may have less obvious symptoms of SDB than typically developing children and therefore screening is often advocated. The original focus of the next clinical question was on 'asymptomatic infants and children with comorbid disorders predisposing to SDB', but as no evidence specifically focused on 'asymptomatic children', the next clinical question was based on children with, and without symptoms of SDB:

> Q4 What is the diagnostic accuracy of pulse oximetry or CRSS for children with comorbid disorders predisposing to SDB?

Despite the literature search identifying 199 potentially relevant publications, only five were specifically relevant to the question and included a very limited number of comorbid conditions (Pierre Robin sequence, Down Syndrome, neuromuscular disease, myelomeningocele and varied disorders).

A summary of the pulse oximetry and CRSS meta-analyses results is shown in table 11 (taken from online supplemental appendix 4, table 4b) and the Q4 Evidence Statements, Recommendation and GPPs are presented below. The full evidence review is presented in online supplemental appendix 4.

Evidence statements

– Pulse oximetry appears to have a low sensitivity and high specificity for diagnosing SDB in children with comorbid disorders. (Very low)

– Pulse oximetry appears to have a low sensitivity and very high specificity for diagnosing mild-to-moderate SDB in children with comorbid disorders. (Very low)

– Based on very limited evidence, CRSS appear to have a moderate sensitivity and low specificity for the diagnosis of SDB in children with neuromuscular disorders and Down syndrome. (Very low)

Table 11 Diagnostic accuracies of pulse oximetry and CRSS for diagnosing sleep-disordered breathing in children with comorbidities

Included data	Number of datasets	Sensitivity (95% CI)	Specificity (95% CI)
Pulse oximetry (all)	4	0.49(0.31 to 0.67)	0.87(0.78 to 0.93)
Pulse oximetry (AHI ≥1)	2	0.43(0.32 to 0.54)	0.93(0.84 to 0.98)
CRSS (all)	3	0.76(0.47 to 0.92)	0.62(0.24 to 0.89)
CRSS (AHI ≥1)	2	0.85(0.35 to 0.98)	0.41(0.13 to 0.76)
CRSS (AHI ≥5)	1	0.62(0.32 to 0.86)	0.87(0.60 to 0.98)

AHI, Apnoea Hypopnoea Index; CRSS, Cardiorespiratory Sleep Study.

Recommendation

► For children with neuromuscular disorders or Down syndrome predisposing to SDB, CRSS can be considered for diagnosing SDB. (Conditional)

Good practice points

✓ Although CRSS can only be recommended as a diagnostic tool for SDB in children with neuromuscular disorders or Down Syndrome, CRSS can be considered as a first line diagnostic tool for children with other comorbidities.
✓ If a CRSS is abnormal, the significance of the findings should be carefully considered and the range of potential management options discussed with the child and their family/carer.
✓ If CRSS findings are inconsistent with the clinical picture, the clinical history should be reviewed giving specific consideration to non-respiratory causes of sleep disorders as outlined in Box 2. Referral to a neurology sleep service for assessment should also be considered.
✓ If a CRSS is not available, pulse oximetry can be considered as an initial diagnostic test for SDB in children with comorbid disorders, but if a test result is abnormal caution must be taken in interpreting the results as desaturations may have varying causes. Referral for more complex studies may be required to assess for hypoventilation and determine the cause and mechanisms of desaturation.
✓ If a pulse oximetry test is normal this does not exclude SDB and clinical review should consider repeat/additional testing.
✓ Clinicians are cautioned from using AHI alone to guide decision-making.
✓ If hypoventilation is suspected, guideline users should refer to the 'Children with comorbidities, Pulse oximetry and CO_2 monitoring' section.

Pulse oximetry and CO_2 monitoring

Pulse oximetry and CO_2 monitoring in children with comorbidities was included in 'Q3 For children undergoing investigation for SDB, does CO_2 monitoring with pulse oximetry improve clinical outcomes, when compared with pulse oximetry alone?' (see 'Children without comorbidities, Pulse oximetry and CO_2 monitoring' section) Please note that due to a lack of direct evidence, diagnostic yield data was included in this review. The Q3 Evidence Statements, Recommendation and GPPs related to children with comorbidities are presented below and the full evidence review is presented in online supplemental appendix 3.

Evidence statements

– Based on limited evidence, the addition of CO_2 monitoring to pulse oximetry may identify more children with neuromuscular disease, Down syndrome and restrictive lung disease who would benefit from the initiation of non-invasive ventilation or adjustments to existing ventilator settings. (Ungraded)
– The addition of CO_2 monitoring to pulse oximetry may also increase the diagnostic yield of diagnosing SDB in children with neuromuscular disease, Down syndrome and restrictive lung disease when compared with pulse oximetry alone. (Ungraded)

Recommendation

► The addition of CO_2 monitoring to pulse oximetry should be considered for children with comorbidities and suspected SDB where hypoventilation is suspected, such as patients with neuromuscular disease or patients suspected of central hypoventilation (eg, congenital central hypoventilation syndrome). (Conditional—by consensus)

Good practice points

✓ If CO_2 measurements are not consistent with the clinical picture, this should be confirmed using a blood gas measurement. If using a transcutaneous CO_2 monitor, this should be recalibrated first. If the problem is not resolved consideration should be given to checking and changing the sensor head membrane.
✓ Pulse oximetry with CO_2 monitoring can be considered as a screening tool to identify hypoventilation in children with comorbidities, or to assess response to adjustments to ventilatory settings in the home setting.
✓ The AASM recommends scoring hypoventilation during sleep when >25% of the total sleep time as measured by either the arterial PCO_2 or surrogate (transcutaneous or end tidal which is more relevant in paediatrics) is spent with a PCO_2 >50 mmHg/6.7 kPa.[3]

Optimal monitoring time and process

When a healthcare provider has decided which diagnostic test to perform (see 'Diagnosis' section), it is important that optimal monitoring times and processes are followed. This section will address:

- Pulse oximetry motion artefact removal and averaging times.
- Optimal monitoring time for pulse oximetry and CRSS.
- Should pulse oximetry and CRSS be acquired over more than one night?

Pulse oximetry motion artefact removal and averaging time

Pulse oximetry forms an important component of the diagnostic pathway. Several factors can contribute to data output from pulse oximeters and these have the potential to impact on diagnostic accuracy. In the last 10–15 years, there have been significant developments in signal processing and measuring technology for oximeters, aimed at improving the estimation of blood SpO_2, and the more accurate exclusion of movement artefact. Although there are a number of studies which highlight the benefits of using oximeters that exclude motion artefact and have short averaging times to accurately predict SDB, there are limited data directly comparing these oximeters with conventional oximeters without motion artefact removal and longer averaging times. It is vital that any oximeter that is used contains technology that optimises the diagnostic accuracy and the next clinical question was:

> Q5 What is the diagnostic accuracy of oximeters with and without motion artefact removal and oximeters with long and short averaging times for children with suspected SDB?

The Q5 Evidence Statement, Recommendation and GPP are presented below and the full evidence review is presented in online supplemental appendix 5.

Evidence statement

– Based on the limited evidence, the addition of motion artefact removal to oximeter signal analysis appears to improve the detection of true desaturation events. (Ungraded)

Recommendation

► Pulse oximetry should be undertaken using an oximeter with a software algorithm to minimise the influence of motion artefact. (Conditional—by consensus)

Table 12 Diagnostic accuracy of 4 hours polysomnography (PSG) sleep monitoring

Age	≤6 months		>6 months, <2 years		Combined data (<2 years)	
Diagnosis	Sensitivity (TP/D+)	Specificity (TN/D-)	Sensitivity (TP/D+)	Specificity (TN/D-)	Sensitivity (TP/D+)	Specificity (TN/D-)
Total AHI	1.00 (48/48)	– (0/0)	0.93 (52/56)	1.00 (1/1)	0.96 (100/104)	1.00 (1/1)
Obstructive AHI	0.98 (46/47)	1.00 (1/1)	0.91 (41/45)	0.92 (11/12)	0.95 (87/92)	0.92 (12/13)
Central AI	1.00 (8/8)	0.83 (33/40)	0.72 (13/18)	0.87 (34/39)	0.81 (21/26)	0.85 (67/79)

AHI, Apnoea–Hypopnoea Index; AI, apnoea indices; D+, number of subjects with the disease; D-, number of subjects without the disease; TN, true negative; TP, true positive.

Good practice point

✓ Based on the Australasian Sleep Association's 'Overnight oximetry for evaluating paediatric obstructive sleep apnoea: Technical specifications and interpretation guidelines',[4] a short pulse oximetry averaging time of 2–3 s should be used when diagnosing SDB in children.

Optimal monitoring time for pulse oximetry and CRSS

For almost all conditions in children, episodes of SDB occur during periods of REM sleep which is accurately determined using PSG. When using level 2, 3 or 4 investigations (table 4), surrogate markers such as heart rate variability are used to determine REM sleep which is often described as active sleep. In children, REM density and duration increase over the course of the night, however AHI does not increase across REM cycles. Thus, the number of REM cycles captured during a period of monitoring might impact on data output. Measuring equipment can be rejected by a child, requiring re-application during the night of study, so a full night of study with high quality data can be a practical challenge and studies may be of a duration much less than a full night of sleep. Understanding the implications of shorter duration studies on diagnostic accuracy would therefore guide clinicians on the need to repeat studies of short duration, leading to the next clinical question:

> Q6 For children with suspected SDB, what is the optimal monitoring time when using pulse oximetry or CRSS?

There was very limited evidence to support this review, with only one study reporting on the diagnostic accuracy of 4 hours of PSG sleep monitoring (containing at least one cycle of REM) to diagnose total AHI, obstructive AHI and CAI in children under 2 years of age with suspected SDB. Full night PSG was used as the gold standard and the results are summarised in table 12.

The Q6 Evidence Statement and GPP are presented below and the full evidence review is presented in online supplemental appendix 6.

Evidence statement

There was minimal evidence to support this review.

– Four hours of PSG monitoring appears to have a high specificity and high sensitivity for diagnosing SDB in children less than 2 years of age when using full night PSG as the gold standard. (Ungraded)

Recommendations

No recommendations can be made based on the limited evidence

Good practice point

✓ Sleep studies, using pulse oximetry or a CRSS, with 4–6 hours of continuous sleep duration should be adequate for diagnosing moderate-to-severe SDB in children. The sleep duration is defined as continuous to allow adequate opportunity for all sleep stages to occur. Combining short episodes of sleep interspersed with wake to create 4–6 hours of sleep recording may miss parts of the sleep cycle and is not advised. This includes children under the age of 2 years, where REM cycles are more evenly dispersed through the night. If a child is older than 2 years of age (when REM sleep is greater in the latter half of the night), or if mild disease is to be excluded, a period of longer than 6 hours is advised

Is one night of pulse oximetry or CRSS monitoring enough?

In the UK there is a desire to use investigations that are simple and practical to undertake, but there is uncertainty as to whether a single night of pulse oximetry or CRSS monitoring provides adequate data, or whether there are certain instances whereby monitoring over several nights may provide an improved diagnostic accuracy for diagnosing SDB. This led to the next clinical question:

> Q7 For children with suspected SDB, does pulse oximetry or CRSS monitoring over more than one night improve the accuracy of diagnosing SDB?

The Q7 Evidence Statements, Recommendation and GPPs are presented below and the full evidence review is presented in online supplemental appendix 7.

Evidence statements

This review had very limited supporting evidence.

– Between-night pulse oximetry metric variations appear to be limited in children without comorbidities. (Ungraded)
– There is not enough evidence to comment on night-to-night variability in pulse oximetry metrics in children with comorbidities, or CRSS metrics in children with, or without comorbidities.

Recommendation

► A single night of pulse oximetry monitoring, ideally consisting of 6 hours of continuous sleep duration, can be considered adequate for identifying SDB in children without comorbidities. (Conditional—by consensus)

Good practice points

✓ A single night of CRSS monitoring should also be considered adequate for identifying SDB in children without comorbidities.

✓ If it is anticipated that a child will poorly tolerate a pulse oximetry probe, consider providing a pulse oximeter for more than one night to acquire at least one night of technically adequate data. Alongside the sleep log data, information on how typical the period of sleep was for the child should also be collected.

✓ If pulse oximetry or CRSS is being considered for diagnosing SDB in children with comorbidities, more than one night of monitoring should be considered, particularly if a parent/carer reports that an initial period of monitoring is not representative of the child's sleep.
✓ If a CRSS is normal but symptoms are ongoing, a repeat CRSS should be performed.

Home monitoring

While inpatient PSG remains the gold standard for diagnosing SDB in children, facilities for inpatient CRSS and PSG in the UK are limited and overwhelmed by demand. In addition, many children, particularly those dependent on a range of technologies including hoists, sleep systems, suction and ventilator equipment, find travel to hospital for sleep studies challenging. Hence, this section investigated if:

- Home PSG, home CRSS and home pulse oximetry are as good as inpatient CRSS.
- The addition of CO_2 monitoring to pulse oximetry is as good as multichannel study monitoring when monitoring mechanical ventilation at home.

Home sleep studies

Inpatient studies normally benefit from the overnight presence of a trained physiologist/nurse who can troubleshoot, and make adjustments, to ensure the maximum amount and quality of the data obtained. However, this is not the case for unattended studies in a child's home and home studies also tend to have fewer channels of physiological data for analysis. Hence, the next question was:

> Q8 For children with suspected SDB, does home CRSS, or home pulse oximetry provide the same clinical outcomes as inpatient CRSS?

The Q8 Evidence Statements, Recommendation and GPPs are presented below and the full evidence review is presented in online supplemental appendix 8.

Evidence statements

– Most parents, or carers of children with suspected SDB, with or without comorbidities, appear to find undergoing a home CRSS a positive experience. (Ungraded)
– The need for repeat monitoring when using home pulse oximetry (Ungraded), home CRSS (Very low) or home PSG (Ungraded) is comparable with inpatient CRSS or inpatient PSG.
– Based on very limited evidence, home CRSS appear to have a high sensitivity and moderate specificity for diagnosing SDB in children. (Very low)
– The diagnostic accuracy of home CRSS appears to be comparable with inpatient CRSS, but there may be an underestimation of AHI with home CRSS compared with inpatient PSG. (Ungraded)

Recommendation

► Home CRSS can be considered for diagnosing SDB in children without comorbidities where the patients and/or carers are deemed appropriate for implementing a home sleep study. If a test result is inconsistent with the clinical picture, or data are incomplete, a repeat study should be offered and consideration should be given as to whether this should be undertaken as an inpatient. (Conditional—by consensus)

Good practice points

✓ Home CRSS can be considered for children with comorbidities and pulse oximetry can be considered for children with, or without comorbidities if the patient and carer are deemed appropriate for home sleep studies.
✓ Care should be taken in defining 'total sleep time' during home sleep studies as it may differ between centres, for example, some may use total recording time, while some may base it on sleep time documented in the overnight sleep diary.
✓ If the data acquired during a home study is fragmented with frequent interruptions due to poor signal quality consideration should be given to repeating the study as an inpatient.
✓ Parents who choose home monitoring should be supported with training in order to optimise data acquisition of sleep studies in the home environment. This training might involve patient leaflets, patient videos or videoconferencing calls with health professionals skilled in setting up sleep studies.

Home ventilation: should CO_2 monitoring be added to pulse oximetry?

After examining if home monitoring is as good as inpatient monitoring (see 'Home sleep studies' section above) and if the addition of CO_2 monitoring to pulse oximetry improves clinical outcomes (see 'Children without comorbidities, Pulse oximetry and CRSS' section), the next clinical question was:

> Q9 For children receiving home mechanical ventilation, is pulse oximetry with CO_2 monitoring as good as multichannel study monitoring when monitoring mechanical ventilation at home?

Children receiving home mechanical ventilation are a clinically varied group with a significant range of underlying problems such as neuromuscular diseases, BPD, cerebral palsy, congenital central hypoventilation syndrome and OSA.[24] For those who have significant disability, bringing them to hospital for complex testing can be a major undertaking, so the ability to perform mechanical ventilation monitoring at home using pulse oximetry and CO_2 monitoring could be of significant benefit. This review investigated if pulse oximetry with CO_2 monitoring is as good as multichannel study monitoring for monitoring children who are receiving home mechanical ventilation.

The Q9 Evidence Statement and GPPs are presented below and the full evidence review is presented in online supplemental appendix 9.

Evidence statement

– Based on the very limited supporting evidence, pulse oximetry with CO_2 monitoring at home may be inferior to inpatient polygraphy for monitoring respiratory events during mechanical ventilation. (Ungraded)

Recommendations

Based on the limited evidence, no recommendations can be made on the use of pulse oximetry with CO_2 monitoring for home monitoring of children receiving home mechanical ventilation.

Good practice points

✓ If children are receiving CPAP or BiPAP therapy, regular monitoring should be provided with a minimum of pulse oximetry and CO_2 monitoring.
✓ When deciding on which type of sleep study to perform, the relative risks and benefits of each should be discussed with the patient and/or carer.

Table 13 Summary of unscheduled admissions to PICU/HDU/overnight inpatient stays following ENT surgery, with, or without preoperative sleep monitoring, in children with and without comorbidities

	Unscheduled stays per 1000 patients (mean±SD) (number of studies)		
Study cohorts	**With sleep monitoring***	**Without sleep monitoring**	***p*‡**
No comorbidities (mixed SDB)	14±16 (4)	35±43 (2)	0.205
No comorbidities (severe OSA)	117±130 (2)	-	-
Mixed	14±17 (7)	33±66 (3)	0.240
Obese†	29 (1)	200 (1)	-

Mixed—mixed groups of children with SDB and with or without comorbidities; No comorbidities—children with SDB determined by pulse oximetry or PSG without comorbidities; Obese—children with SDB and obesity.
*Pulse oximetry (4 studies), polysomnography (PSG) (10 studies), pulse oximetry and PSG (1 study).
†Reported data from 2 different studies.
‡Independent t-tests between mean data across studies
§$p = 0.743$ between 'No comorbidities (Mixed SDB)' and 'No comorbidities (Severe OSA)' 'With sleep monitoring' data
ENT, ear, nose and throat; HDU, high dependency units; OSA, obstructive sleep apnoea; PICU, paediatric intensive care unit; SDB, sleep-disordered breathing.

✓ Data download from a CPAP device or ventilator can help complement results from a sleep study, but operators should note that many ventilator algorithms, such as AHI, have not been validated in children.

Narcolepsy

Narcolepsy is a lifelong neurological disorder characterised by EDS, that is quantified using Epworth Sleepiness scoring. Additionally, cataplexy and other dissociations of REM sleep may be present, but a diagnosis of narcolepsy is often not clinically clear and there are many causes of EDS, especially in adolescents. Cataplexy is the sudden loss of muscle tone, usually precipitated by heightened emotion predominantly in facial and neck musculature but may be associated with full body loss of tone leading to collapse, during which time the individual is conscious.

The MSLT consists of five scheduled naps separated by 2-hour intervals across the day. Sleep latency and REM latency are recorded, yielding a quantitative measure of sleep propensity as well as detecting sleep-onset REM episodes. Currently, PSG and MSLT are necessary to confirm a diagnosis of narcolepsy, and rule out a diagnosis of SDB, but these are not readily available throughout the UK, therefore, in practice, the criteria for referral for such specialist investigation, either in a sleep laboratory or neurophysiology department setting are purely clinical so the next clinical question was:

> Q10 For children and young people with daytime sleepiness and normal CRSS what characteristics are associated with a diagnosis of narcolepsy?

The Q10 Evidence Statements, Recommendations and GPPs are presented below and the full evidence review is presented in online supplemental appendix 10.

Evidence statements

There is very limited evidence supporting this review.

– Cataplexy is present in the majority of children at the onset of narcolepsy, however, its manifestations may be subtle and narcolepsy may be present without cataplexy. (Ungraded)
– Hypnagogic and hypnopompic hallucinations and sleep paralysis are much more common in children with narcolepsy than in the general population. (Ungraded)
– Although sleep attacks are strongly associated with a diagnosis of narcolepsy in children, they are not specific to the disorder of narcolepsy. (Ungraded)

Recommendations

► If SDB is excluded, or effectively treated, and EDS persists, other diagnoses including narcolepsy, with possible coexistent cataplexy, sleep paralysis, hypnagogic and hypnopompic hallucinations and circadian rhythm disorders should be considered. (Conditional—by consensus)
► As cataplexy may be subtle, both child and parents/carers should be asked about head nods, neck/shoulder posturing and eyelid/facial droop. These are typically associated with laughter, but may also be associated with anger or frustration. (Conditional—by consensus)
► Both child and parents/carers should be asked about sleep paralysis, hypnagogic and hypnopompic hallucinations. (Conditional—by consensus)
► Both child and parents/carers should be asked about sleep onset and wake up times to elicit total sleep time and sleep latency to exclude a circadian rhythm disorder (that can be associated with EDS). (Conditional—by consensus)

Good practice points

✓ An awareness of rare conditions in children, which may primarily present with EDS, should always be maintained.
✓ As the associated symptoms of narcolepsy may be subtle or may not be volunteered, directed questions in the clinical history should be used to elicit a possible diagnosis of narcolepsy in children and initiate referral to a specialist paediatric sleep service for specialist assessment and investigation. The current standard of diagnostic investigation is a 1-week period (minimum, preferably 2 weeks) of actigraphy with PSG and MSLT. These investigations should be performed in line with AASM/ESRS guidance.[5 6]
✓ Children with narcolepsy should be under the care of a clinician with special expertise in the management of narcolepsy. This may be a paediatric neurologist or a sleep physician, depending on local service arrangements.

Sleep assessments related to children undergoing tonsillectomy

Current UK ENT guidelines (Safe Delivery of Paediatric ENT Surgery in the UK[25]) advise that preoperative OSA testing is not always necessary if a child presents with a history of, and evidence of, adenotonsillar hypertrophy. However, adenotonsillectomy in children is sometimes associated with post-operative complications such as respiratory compromise and bleeding, which can require one-to-one nursing in the hours after surgery, or, in some cases, admission to HDU or PICUs. Pulse oximetry may predict those at increased risk of peri-operative complications, so the final clinical question was:

> Q11 For children with SDB, does oxygen saturation monitoring before tonsillectomy (with or without adenoidectomy) improve clinical outcomes?

A summary of the rate of unscheduled admissions to PICU/HDU/overnight inpatient stays following ENT surgery with and without preoperative sleep monitoring is shown in table 13 (taken from online supplemental appendix 11, table 11b). Due

to a lack of supporting evidence which focused on pulse oximetry for preoperative sleep monitoring, studies using PSG were included in the evidence review. No studies used CRSS for preoperative sleep monitoring.

Despite the large SD in the 'No comorbidities (Severe OSA)' study cohort, within the 'mixed' groups, two studies linked the need for unscheduled admissions to PICU/HDU/overnight inpatient stays to the presence of comorbidities [26 27]. Four also commented on a link between unscheduled admissions and severity of OSA/SDB[28–31] (table 13). Comorbidities across the 'mixed' group studies included neurological disorders, Down syndrome, obesity, respiratory disorders, asthma, developmental disorders and craniofacial disorders.

One study within the 'Mixed' group also reported on three subsets within their study population:

i. Children ≤1.5 years
ii. Children between >1.5 and 2.5 years; and
iii. Children between >2.5 and 3.5 years.[30]

Although the study found no significant difference in the rate of significant hospital admission events between the three age groups ($p = 0.67$), multivariate logistical analysis showed that children under the age of 1.5 years were at a significantly higher risk of peri- or post-operative admission events (13.7 [6.5–29.0], $p < 0.001$, odds ratio (OR) [95% confidence intervals (CI)]).[30] This result was echoed in two further studies, where age <2 years ($p < 0.01$)[29] [31] and age <3 years (4.10 [1.79, 9.26], OR [95% CI])[27] were deemed higher risk factors of peri- or post-operative complications.

The Q11 Evidence Statements, Recommendations and GPPs are presented below and the full evidence review is presented in online supplemental appendix 11.

Evidence statements

Based on primarily retrospective evidence:

- Preoperative sleep monitoring (pulse oximetry or PSG) before tonsillectomy (with or without adenoidectomy) does not appear to reduce the need for unscheduled admissions to PICU/HDU/overnight inpatient stays for most children, with or without comorbidities, and symptoms of SDB. (Very low)
- Diagnosing severe OSA in children before tonsillectomy (with or without adenoidectomy) may reduce the need for unscheduled perioperative admissions to PICU/HDU/overnight inpatient stays. (Ungraded)
- Preoperative sleep monitoring (pulse oximetry or PSG) before tonsillectomy (with or without adenoidectomy) may reduce unscheduled admissions to PICU/HDU/overnight inpatient stays in children with obesity and SDB. (Ungraded)
- Preoperative sleep monitoring (pulse oximetry or PSG) before tonsillectomy (with or without adenoidectomy) may reduce unscheduled admissions to PICU/HDU/overnight inpatient stays in children with comorbidities . (Ungraded)

Recommendations

- ► Routine preoperative sleep monitoring as a basis for surgical decision-making is not recommended in children without comorbidities who are over the age of 2 years, and in whom severe OSA is not suspected. (Conditional—by consensus)
- ► Preoperative sleep monitoring before tonsillectomy (with or without adenoidectomy) should be considered for children who are less than 2 years of age to allow preoperative planning. (Conditional—by consensus)

Good practice points

- ✓ Preoperative CRSS sleep monitoring before tonsillectomy (with or without adenoidectomy) may be considered for children of all ages with comorbidities (eg, obesity, Down syndrome, cerebral palsy, neuromuscular disease) and suspected SDB to confirm a diagnosis of SDB and allow preoperative planning.
- ✓ A preoperative pulse oximetry sleep study before tonsillectomy (with or without adenoidectomy) may be considered for children without comorbidities with suspected severe OSA.
- ✓ Sleep monitoring following tonsillectomy (with or without adenoidectomy) may also be considered for children with severe OSA, with, or without comorbidities, if there is a clinical need (eg, less than 2 years of age, Down syndrome, obesity, cerebral palsy, neuromuscular disease, persistent need).

INFORMATION ON ISSUES AROUND APPROPRIATE SERVICE PROVISION IN THE UK

Staffing, training and facilities

The Royal College of Paediatrics and Child Health training syllabus includes various learning objectives related to paediatric sleep medicine, including a special interest module in sleep. With support from tertiary centres this would equip paediatricians with the skill, knowledge and attributes to run and deliver a local service including diagnostic aspects of care. Physiologists already have a well-established training and accrediting system that will encompass all the capabilities required to run, analyse and report sleep tests.

A local service in a district hospital should have a clinician well versed in the use of clinical questionnaires and pulse oximetry (home and in-hospital) as diagnostic tests. Clinicians in local hospitals should also have access to a tertiary referral centre as part of a clinical network. This would facilitate clinical discussion and advice.

A tertiary specialist centre should have access to clinicians with a high level of experience and training in paediatric sleep medicine, who may well come from respiratory or neurology/neurodisability backgrounds. The unit should have the ability to perform and interpret the whole range of sleep investigations, including gas exchange (pulse oximetry and CO_2 monitoring) and CRSS. Many of these centres would also offer detailed PSG. The service would be underpinned by expert physiologists and specialist nurses and would also offer a respiratory support service with a ventilation support team.

Audit criteria

Suggested audit criteria for assessing the implementation of the guideline are listed below:

1. Unexpected post-operative complications following tonsillectomy/adenoidectomy.
2. The use of pre-operative SBD studies before tonsillectomy/adenoidectomy.
3. The need for repeated home SDB studies versus inpatient SDB studies.

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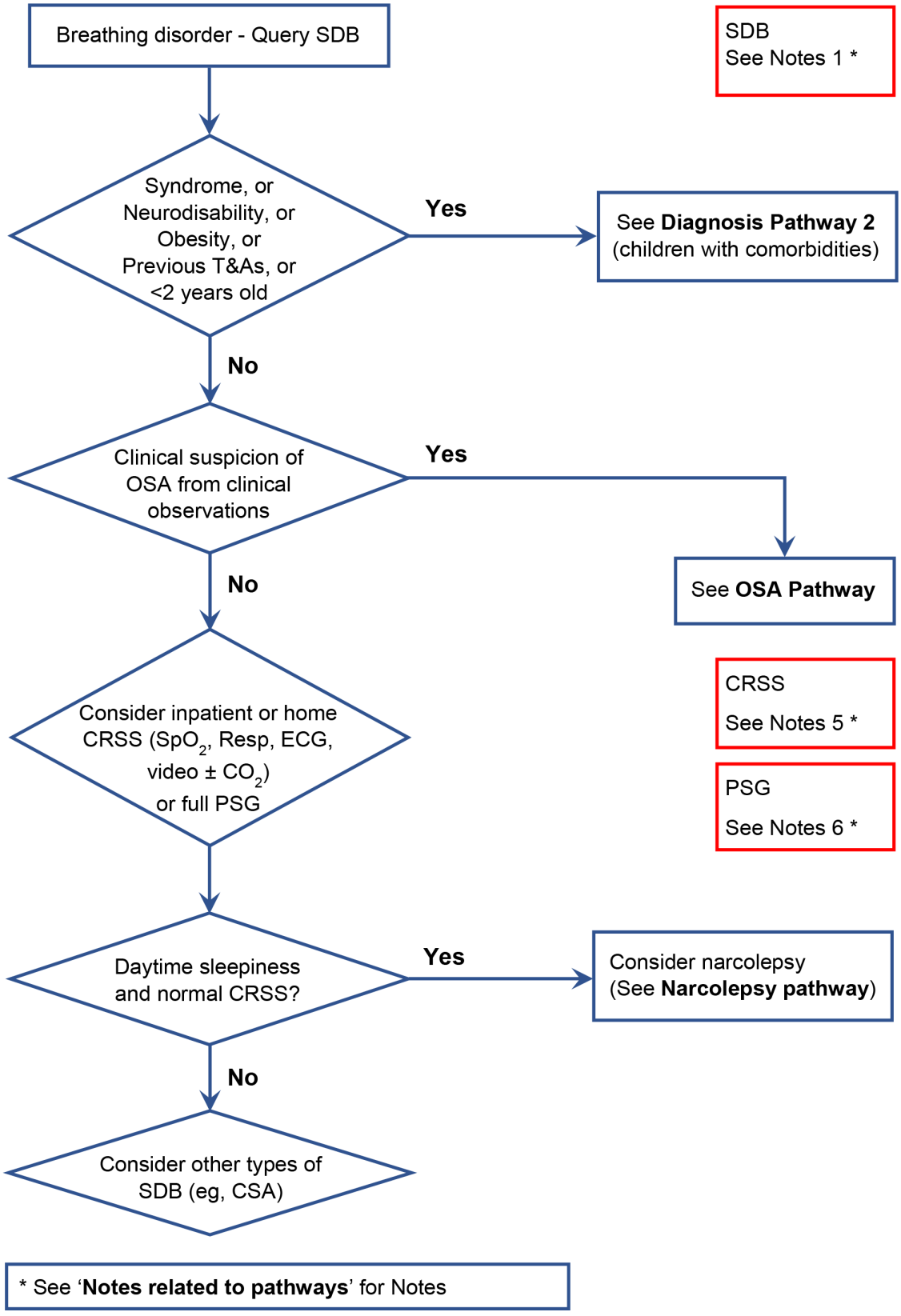
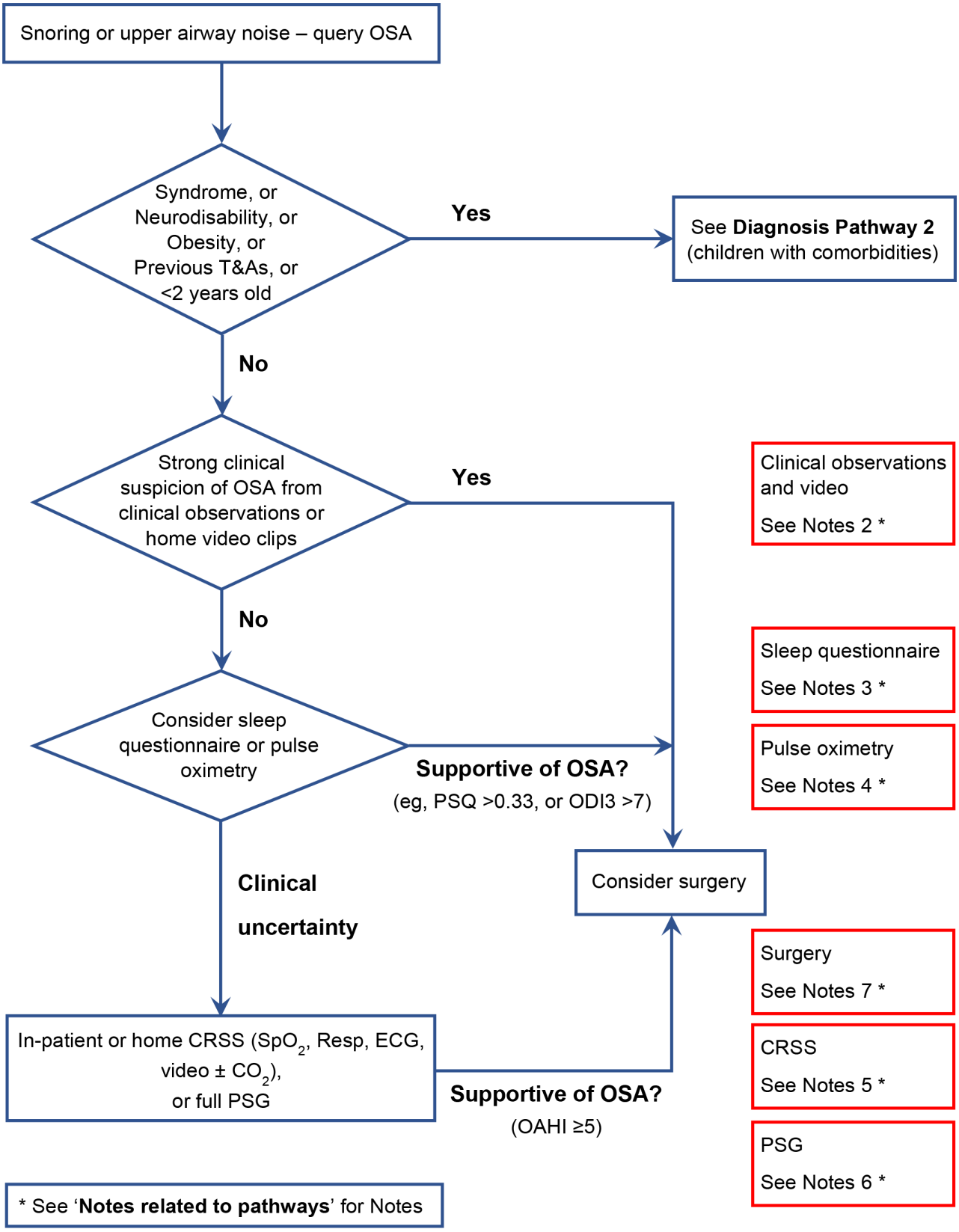
APPENDIX 1 – CLINICAL PATHWAYS/OPTIMAL PROCESS INFORMATION

Diagnosis Pathway 1 (Children without comorbidities)



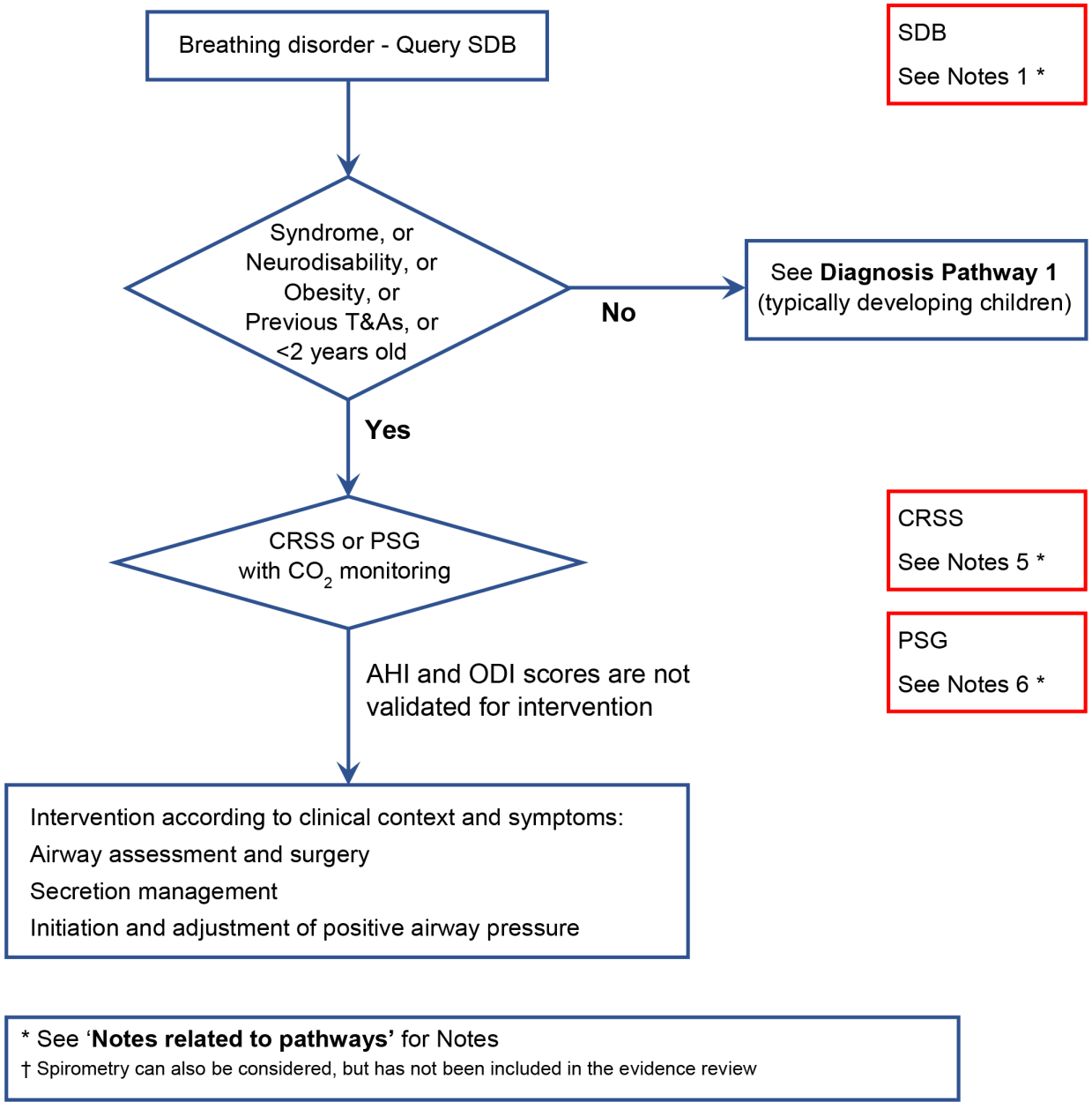
CRSS, cardiorespiratory sleep study; CSA, central sleep apnoea; OSA, obstructive sleep apnoea; PSG, polysomnography; SDB, sleep-disordered breathing; SpO2, oxygen saturation; T&As – tonsillectomy and adenoidectomy.

Obstructive sleep apnoea pathway



CRSS, cardiorespiratory sleep study; OAHI, obstructive apnoea hypopnoea index; ODI3, oxygen desaturation index; OSA, obstructive sleep apnoea; PSG, polysomnography; PSQ, paediatric sleep questionnaires; SDB, sleep-disordered breathing; SpO2, oxygen saturation.

Diagnosis Pathway 2 (Children with comorbidities)



CRSS, cardiorespiratory sleep study; OAHI, obstructive apnoea hypopnoea index; ODI3, oxygen desaturation index; OSA, obstructive sleep apnoea; PSG, polysomnography; PSQ, paediatric sleep questionnaires; SDB, sleep-disordered breathing; SpO2, oxygen saturation.

Pulse oximetry optimal monitoring time/process

Optimal pulse oximetry settings for monitoring SDB in children

Oximetry variable	Optimal setting(s)
Motion artefact removal	Motion artefact removal should be used.
Averaging time	2–3 s
Monitoring time (hours)	4–6 hours continuous sleep duration if moderate-to-severe SDB is suspected.
	>6 hours continuous sleep duration if mild SDB is suspected.
Monitoring time (nights)	1 night for children without comorbidities.
	Consider >1 night for children with comorbidities.
	Consider >1 night if initial period of monitoring not representative of child's sleep.

Pulse oximetry measurements suggestive of an abnormality in children >2 years of age

Oximetry variable	Abnormal measurement
ODI4	A cut-off of>4/hr
ODI3	A cut-off of>7/hr
Mean SpO_2	<95%
Clustering and depth of desaturation events should also be considered (eg, mean >4% desaturation nadir <90%, or 3 episodes of desaturation <80%)	

Precautions when analysing home pulse oximetry

Care should be taken when defining 'total sleep time' as different centres can use different definitions (eg, total recording time or sleep time documented in an overnight sleep diary)

Oximetry cannot discriminate between obstructive or non-obstructive events or determine hypoventilation.

CRSS optimal monitoring time/process

Optimal CRSS monitoring times for diagnosing SDB in children

CRSS variable	Optimum
Monitoring time (hours)	4–6 hours continuous sleep duration if moderate-to-severe SDB is suspected. >6 hours continuous sleep duration if mild SDB is suspected.
Monitoring time (nights)	1 night for children with/without comorbidities. >1 night if initial period of monitoring not representative of child's sleep.

Considerations if a CRSS is normal

If a cardiorespiratory sleep study is normal but symptoms are ongoing, a repeat cardiorespiratory sleep study should be performed.

If a child has a normal CRSS, but has daytime sleepiness, narcolepsy can be considered (see the Narcolepsy pathway).

Home monitoring pathway

CRSS, cardiorespiratory sleep study.

Home ventilation

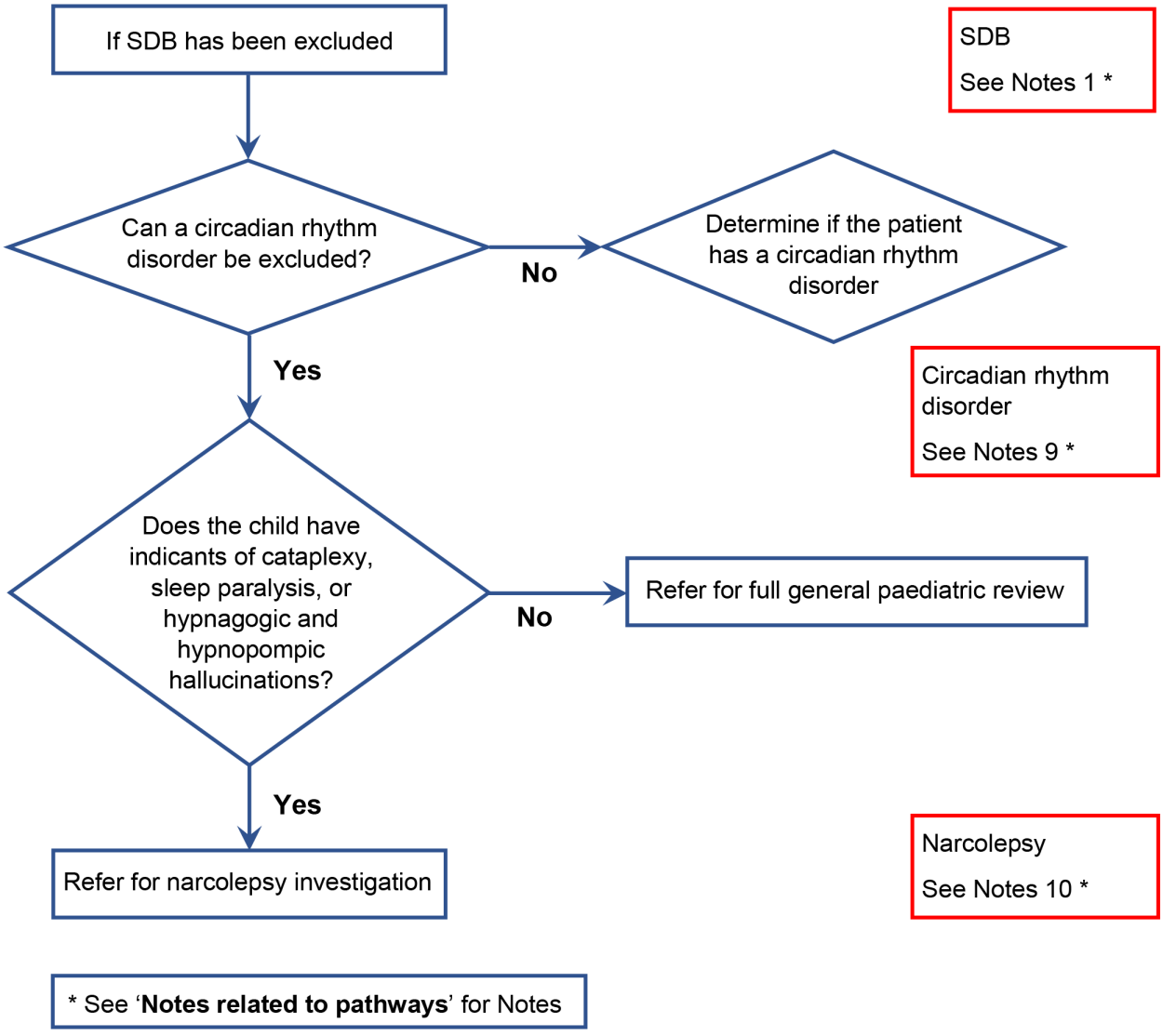
Pulse oximetry and CO_2 monitoring

CPAP or BiPAP treatment

For children receiving continuous positive airway pressure therapy (CPAP) or bi-level positive airway pressure (BiPAP), regular monitoring should be provided with a minimum of pulse oximetry and carbon dioxide monitoring.

When downloading from a CPAP device or ventilator, it should be noted that many ventilator algorithms, such as apnoea hypopnoea index (AHI), have not been validated in children.

Narcolepsy pathway



SDB, sleep-disordered breathing.

Notes related to pathways

Notes 1	Sleep-disordered breathing (SDB) An awareness of rare conditions in children, which may primarily present with excessive daytime sleepiness, should always be maintained.
Notes 2	Clinical observations & video recordings There is currently insufficient evidence to make recommendations for use of sleep video or audio recordings to diagnose SDB. Video and audio recordings do not have validated scoring systems. Clinicians use these in a similar way to clinical observation to support intervention to treat SDB, but there is no method for scoring overall severity in sleep.
Notes 3	Sleep questionnaires SRBD-PSQ ≥0.33 and OSA-18 ≥0.60 questionnaires are recommended for diagnosing moderate-to-severe obstructive sleep apnoea (OSA) (AHI ≥5) in children without comorbidities. Questionnaires are not validated in children <2 years of age. Due to a lack of evidence, the use of sleep questionnaires for diagnosing SDB in children with comorbidities is not supported at this time. Sleep questionnaires will not detect mild SDB. If higher diagnostic certainty is needed, further monitoring with pulse oximetry, CRSS or PSG are advised.
Notes 4	Pulse oximetry Pulse oximetry can be considered as a first-line diagnostic test for SDB in children, but a normal study does not exclude the presence of mild to moderate SDB. Pulse oximetry ODI4 >4/hour or ODI3 >7/hour is supportive of a diagnosis of SDB. Pulse oximetry does not discriminate between obstructive and non-obstructive events, and for this reason should be used with caution in children under 2 years and for children with comorbidities for diagnosing OSA. A normal pulse oximetry study does not exclude the possibility of hypoventilation. The addition of carbon dioxide monitoring (CO_2) to pulse oximetry does not increase the diagnostic yield in children without comorbidities. The addition of CO_2 monitoring to pulse oximetry can be considered for children with comorbidities and suspected SDB where hypoventilation is suspected.
Notes 5	Cardiorespiratory sleep studies (CRSS) CRSS can be considered as a first line diagnostic tool for children with, or without comorbidities. The addition of CO_2monitoring to CRSS probably does not increase the diagnostic yield in children without comorbidities. The addition of CO_2 monitoring to CRSS can be considered for children with comorbidities and suspected SDB where hypoventilation is suspected.
Notes 6	Polysomnography (PSG) PSG provides information on sleep architecture, as well as arousals related and unrelated to respiratory events. PSG is mostly performed with supervision and as an inpatient; unsupervised diagnostic PSG can be done in the home setting with good effectiveness. PSG is done to diagnose sleep behaviour disorders, eg, parasomnias, and to exclude SDB, for example, in narcolepsy. PSG needs to be done in conjunction with multiple sleep latency testing to diagnose narcolepsy.
Notes 7	Surgery Adenotonsillectomy is an effective treatment for OSA, especially in typically developing children (ie, those without comorbidities). OSA might not necessitate surgery, especially if mild when a 'wait and see' approach or medical therapy may be appropriate. Surgery should be agreed between clinicians and patients and/or parents/carers. Surgery may require local health board agreements.
Notes 8	Home CRSS Home CRSS can be considered for children with, or without comorbidities if the patient and carer are deemed appropriate for home sleep studies.
Notes 9	Circadian rhythm disorder Sleep onset and wake up times should be discussed with the patient and/or carer to elicit sleep time and sleep latency.
Notes 10	Narcolepsy As the pathognomonic symptoms of narcolepsy may be subtle, or may not be volunteered, directed questions in the clinical history should be used to elicit, or exclude a diagnosis of narcolepsy in children. As cataplexy may be subtle, both child and parents/carers should be asked about head nods, neck/shoulder posturing and eyelid/facial droop. These are typically associated with laughter but may also be associated with anger or frustration. Both child and carer(s) should be asked about sleep paralysis and hypnagogic and hypnopompic hallucinations.

AHI, Apnoea–Hypopnoea Index; CRSS, Cardiorespiratory Sleep Studies; ODI3, 3% Oxygen Desaturation Index; ODI4, 4% Oxygen Desaturation Index; OSA, obstructive sleep apnoea; PSG, polysomnography; SRBD-PSQ, Sleep-related Breathing Disorder scale of the Paediatric Sleep Questionnaire.

APPENDIX 2 – GUIDELINE DEVELOPMENT GROUP MEMBERS

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Dr Daniel Tweedie	Consultant Paediatric Otolarynologist Evelina London Children's Hospital, London
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Dr Andrea Whitney	Paediatric Neurologist University Hospital Southampton NHS Foundation Trust
Ms Michelle Baker	Parent Representative (July 2018 - January 2021)
Ms Laura Buggy	Parent Representative (July 2018 - February 2020)

APPENDIX 3 – CLINICAL QUESTIONS

Q1 What is the diagnostic accuracy of using a sleep questionnaire, a combined sleep questionnaire and clinical assessment, sleep video recording or sleep audio recording to identify sleep-disordered breathing in children with suspected sleep-disordered breathing?

Q2 For children with suspected sleep-disordered breathing, what is the diagnostic accuracy of pulse oximetry and cardiorespiratory sleep studies?

Q3 For children undergoing investigation for sleep-disordered breathing, does carbon dioxide monitoring with pulse oximetry improve clinical outcomes, when compared with pulse oximetry alone?

Q4 What is the diagnostic accuracy of pulse oximetry or cardiorespiratory sleep studies for children with comorbid disorders predisposing to sleep-disordered breathing?

Q5 What is the diagnostic accuracy of oximeters with and without motion artefact removal and oximeters with long and short averaging times for children with suspected sleep-disordered breathing?

Q6 For children with suspected sleep-disordered breathing, what is the optimal monitoring time when using pulse oximetry or cardiorespiratory sleep studies?

Q7 For children with suspected sleep-disordered breathing, does pulse oximetry or cardiorespiratory sleep study monitoring over more than one night improve the accuracy of diagnosing sleep-disordered breathing?

Q8 For children with suspected sleep-disordered breathing, does home respiratory polygraphy, or home pulse oximetry provide the same clinical outcomes as inpatient cardiorespiratory sleep studies?

Q9 For children receiving home mechanical ventilation, is pulse oximetry with carbon dioxide monitoring as good as multichannel study monitoring when monitoring mechanical ventilation at home?

Q10 For children with daytime sleepiness and normal cardiorespiratory sleep studies, what characteristics are associated with a diagnosis of narcolepsy?

Q11 For children with sleep-disordered breathing, does oxygen saturation monitoring before tonsillectomy (with or without adenoidectomy) improve clinical outcomes?

APPENDIX 4 – STAKEHOLDER ORGANISATIONS

Association of Respiratory Technology and Physiology
British Association Paediatric Otolaryngology
British Paediatric Neurology Association
British Paediatric Respiratory Society
British Paediatric Sleep Association
British Sleep Society
National Paediatric Respiratory and Allergy Nurses Group
Royal College of Paediatric and Child Health

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